Efficacy and Economics of Riparian Buffers on Agricultural Lands

State of Washington

Phase I

Work In Progress

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SUBMITTED TO

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Executive Summary

While recognizing the importance of protecting listed anadromous salmonids that migrate through streams on agricultural lands, the Washington State agricultural community is concerned about the potential mandating of fixed-width riparian buffer zones. Natural resource agencies, including the Washington Department of Fish and Wildlife and the National Marine Fisheries Service, have proposed mandatory, fixed-width riparian buffers on agricultural lands throughout the state. Arbitrary or uniform imposition of fixed-width riparian buffers on agricultural lands raises serious issues related to private property, economic impacts, and the most effective means of salmon habitat recovery and protection.

In response to these concerns, the Washington Hop Commission, Ag Caucus, of the Ag Fish Water Process, retained GEI Consultants, Inc. (GEI), Pacific Northwest Project (PNWP) and Mason Bruce & Girard (MBG) to review the functions and design dimensions for riparian buffers, their use and efficacy, their applicability to agricultural lands, and potential alternatives to fixed-width riparian buffers.

This report has two primary objectives: (1) to determine what scientific and technical data and analyses have been applied to the issue of agricultural buffers, and whether the data and analyses are being appropriately matched to buffer zone applications, and (2) to evaluate the economic costs associated with the proposed land set-asides. The general value of riparian vegetation for fish, wildlife, and water quality is well established in the literature and is not disputed by our findings. The goal of this study is not to determine if buffers are good for these purposes. It is to determine whether it is necessary to broadly prescribe buffers of a specific width on agricultural lands to protect listed salmon. The report relies primarily on reviews of peer-reviewed scientific literature and is therefore consistent with use of Best Available Science regulations (Appendix B).

Large, fixed-width riparian buffers have five primary economic costs: (1) the cost to remove land from production, (2) the loss of economic benefits from agricultural production on those lands, (3) costs to monitor, administer, and maintain buffers, (4) loss of tax base, and (5) loss of economic infrastructure.

The prototypes for current buffer-width recommendations derive primarily from models of timberland set-asides in the Pacific Northwest forests. Thus the science relied on to formulate buffer widths is mostly forest-based. There are, however, important shortcomings to applying methodologies and science associated with timberland to agricultural lands. The landscape, stream gradients, harvest practices, and impacts all differ.

The six primary functions and values attributed to riparian buffers in forests are large wood recruitment, shade, streambank stability, litter-fall, sediment filtration, and floodplain processes. The Forest Ecosystem Management Assessment Team (FEMAT) process developed models to determine how much timber to preserve in riparian zones adjacent to harvested areas. Those models led to buffers up to 300 feet or more, depending on floodplain limits, on each side of a stream.

The function that requires the widest set-aside is recruitment of large woody debris (LWD), which improves the quality and quantity of fish habitat in small forest streams. In reviewing literature provided by resource agencies to the Ag Caucus, it appears that data gathered in the timber assessment process and especially curves for LWD are the principal basis for wide buffer recommendations in agricultural areas. Also, the general value of wildlife habitat is emphasized in this literature.

The scientific literature of agricultural buffer widths on to streams in the Pacific Northwest is quite limited. In general, agricultural impact analysis suggests riparian functions other than LWD are far more important on agricultural lands. Vegetation traps sediment, filters pollutants, retains storm water, and stabilizes streambanks on agricultural lands. An important and related issue on agricultural lands is protecting streams from direct and indirect impacts of domestic animals. Peer reviewed studies found applicable in this report suggest that relatively narrow buffers of 10 meters (33 feet), or less, can be highly effective in protecting ecological functions against these types of agricultural impacts. Physical stability and filtration absorption is provided by roots adjacent to the channel and up to the stream's normal high-water mark. In addition, separation of livestock from the stream by only a small margin has proven effective in restoration of water quality and physical habitat. With proper livestock management, fencing may not be needed.

Thermal protection from shade is another desirable riparian function that is dependent on a number of site-specific factors. In larger lowland streams, thermal benefits from riparian shade are reduced. Data and thermodynamic considerations show that small streams can be protected from overheating on a diurnal cyclic basis; however, a relatively narrow buffer within a few meters of the stream can be effective in blocking direct sunlight from the water surface.

Cost effective approaches to protecting salmon streams on agricultural lands will benefit both small agricultural enterprises and the State of Washington. Agricultural production, including agricultural services and food processing, generates almost $8 billion annually in state income. The agricultural industry is a leading economic sector in several rural counties, in some cases producing more than $100,000,000 annually in farm gate production values. This production, in turn, produces ongoing economic activity in other sectors.

Index values can be used to estimate economic impacts of fixed-width riparian buffers in a given county. On a per mile basis, the costs of buffer zones for select counties reviewed in this report could range from $11,000 to $81,000 for lost crops, $67,000 to $88,000 for lost dairy production, and $45,000 to $95,000 for reduced land values. The loss of total direct and indirect county income per 100 acres of riparian set-backs could range between $190,000 and $240,000 per year.

Cost analyses, marginal benefit assessments, and cost effective analyses can be useful means for assessing marginal benefits and trade-offs within economic sectors. These tools can be used accurately at the county or regional level to compare the costs of variable width buffers or other approaches. Additionally, local enterprise economic models are in development that will help individuals evaluate and understand the economic cost of decisions that affect their land.

One alternative to mandatory, fixed-width riparian buffers that may be preferable to farmers and ranchers would be a voluntary, incentive based program that may include variable width buffers. The agricultural community has already adopted many conservation practices based on local environmental needs and identifiable conditions in an ongoing betterment process that includes economic considerations. Variable width buffers that consider land use, gradient, and proximity to points of maximum return flows are preferable and will likely be more effective than fixed-width buffers. A more in-depth analysis of needs and alternatives is proposed for Phase II of this work in progress. A possible linkage could come from on-going watershed planning. Phase II of this research will elaborate on methods to encourage habitat improvement on agricultural lands and provide regulatory and economic certainty.

In summary, after reviewing numerous peer-reviewed studies related to agriculture, we conclude that riparian buffers, based on site potential tree heights of up to 300 feet wide, often greatly exceed what is required to protect water quality and the ecological function of aquatic habitat on agricultural lands. Fixed-width buffers do not offer targeted solutions to site-specific issues. Fixed widths are independent of site-specific gradient, overland and channel flow regimes, and locations of maximum return flow. When buffers zones are wider than a site requires, it can be difficult to justify the adverse economic impacts that a mandated width would produce. For alternative purposes, such as enhanced habitat connectivity to benefit terrestrial wildlife, greater widths may be desirable, but go beyond what is necessary to recover listed fish. Riparian buffer zones are ecologically beneficial; however, the width and composition of a buffer zone should be tied to specific management objectives.

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Section 1 - Introduction

1.1 Background and Purpose

The Washington Department of Fish and Wildlife (WDFW) and National Marine Fisheries Service (NMFS) are recommending mandatory, fixed-width buffers as the primary tool to reduce adverse agricultural impacts to salmon recovery under the Endangered Species Act. The regulatory agencies recommend mandatory buffers as a means to improve water quality and retain or enhance aquatic, terrestrial, and riparian habitat for fish and wildlife (Mankowski and Landino, 2001; Knutson and Naef, 1997). Some counties have adopted agency recommendations.

While recognizing the importance of protecting listed anadromous salmonids that migrate through streams on agricultural lands, the Washington State agricultural community is concerned that mandatory, fixed-width riparian buffers could have severe economic consequences, including putting many small enterprises out of business. In response to these concerns, the Washington Hop Commission, Ag Caucus, of the Ag Fish Water Process, retained GEI Consultants, Inc. (GEI) and its teaming partners, PNWP and MBG, to review the functions and design dimensions for riparian buffers, their use and efficacy, their applicability to agricultural lands, and potential alternatives to fixed-width riparian buffers (including variable width buffers).

This report has two primary objectives: (1) to determine what scientific and technical data and analyses have been applied to the issue of agricultural buffers, and whether the data and analyses are being appropriately matched to buffer zone applications, and (2) to evaluate the economic costs associated with the proposed land set-asides.

A literature review was undertaken to assess the scientific and technical bases for proposed agricultural riparian buffers, and whether the proposed buffer applications are consistent with goals and needs specific to endangered salmonid recovery. The literature review is focused on a relatively limited set of scientific investigations dealing with a specific set of agricultural management issues. The review is not intended to be a comprehensive review of riparian science although the basic ecological functions of riparian areas are addressed.

Specific questions to be answered relative to the science and technical function of agricultural buffers include:

1. What is the body of science, scientific analyses, and reviews pertinent to an evaluation of agricultural buffers?
2. What do the empirical data and analyses suggest about buffer requirements to manage adverse agricultural impacts to salmon habitat?
3. When adverse agricultural impacts are present, what management practices can reduce the need for riparian buffers or the required width of riparian buffers?
4. What are the potential economic costs of buffer zone management alternatives?
5. What are appropriate bases for evaluating and comparing economic impacts and trade-offs?

1.2 Authorization

GEI Consultants, Inc. (GEI) was authorized to complete the scope of work for this report by a contract, dated June 1, 2002 between Washington Hop Growers Association and GEI. GEI's subcontractors in this authorized work include Pacific Northwest Project of Kennewick, WA (Dr. Darryll Olsen) and Mason, Bruce & Girard Inc. of Portland, OR. (Mr. Michael Bonoff).

1.3 Scope of Work

In completion of this report, GEI and its teaming partners completed the following scope of work:

1. Reviewed and summarized literature and references provided as Best Available Science by Washington Department of Fish and Wildlife as justification for agricultural buffer recommendations (Appendix A).
2. Reviewed relevant scientific and technical literature related to riparian buffer zones. The review was not intended to be exhaustive, but focused on minimum buffer width that could significantly reduce known impacts to water quality and salmonid species on agricultural lands.
3. Summarized findings and conclusions in this report.

1.4 Project Personnel

The following personnel played key roles in the development of this report:

John Pizzimenti, Ph.D.	Project Manager, GEI
Ginger Gillin, M.S.	Fisheries Biologist, GEI
Duane McClelland, E.I.T.	Reviewer, Editor, GEI
Darryll Olsen, Ph.D.	Natural Resource Economist, PNWP
Michael Bonoff, M.S.	Limnologist / Ecologist, MBG

Jennifer Ennis M.S., J.D.	Biologist / Regulatory Specialist, MBG
Hushmandi Ziari, Ph.D.	Minnesota IMPLAN Model Specialist

In addition to the above staff, we received comments, literature and or general assistance from several outside persons and anonymous reviewers of various drafts from Oregon State University, Iowa State University, National Resource Conservation Service, National Marine Fisheries Service, Skagit County Washington, Ag Caucus, the Washington Agricultural Caucus, and the Washington Department of Agriculture. However, this document is the independent product of GEI and our subcontractors.

Section 2 - Overview

2.1 Rationale for Fixed-Width Riparian Buffers

The proposed width of agricultural riparian buffer zones and the activities that are allowed within these zones are based on a complex set of timber harvest regulations in the Washington Forest and Fish Report (Appendix A.10). Buffer widths in timber zones in excess of 300 feet on both sides of a stream were established primarily to ensure continued recruitment of large woody debris (LWD) to enhance salmonid pool habitat (FEMAT, *op.cit*). Forest removal impairs the recruitment of LWD until a new forest matures. Temporary loss of mature forests can adversely impact aquatic habitats for hundreds of years. Riparian buffers provide other ecological benefits, including nutrients, shade, bank stability, and terrestrial habitat (FEMAT, *op.cit*.). Each of these benefits can be provided within the buffer width established for LWD.

2.2 State's Best Available Science for Riparian Buffers

The State of Washington and NMFS (Mankowski and Landino, 2001) provided a compendium of literature citations to the Ag Fish Water's Agricultural Caucus. The compendium is considered by WDFW and NMFS to represent the Best Available Science (BAS) in support of proposed fixed-width, agricultural riparian buffers. This document is a bound collection of hundreds of references from 15 different source documents. Two of the documents pertain directly to agricultural data and the remaining 13 documents pertain to forests or other subjects or focal points (Appendix A).

2.3 Limited Applicability of State's Science for Riparian Buffers

In our opinion, the compendium of literature citations provided by the State does not meet traditional BAS criteria and does not provide an adequate basis for establishing appropriate sized buffers on agricultural lands. The compendium describes itself as follows: "Please recognize the proposed approach represents a synthesis of a consolidation of a large amount of scientific information and best professional judgment by natural resource scientists" (Mankowski and Landino, *op cit*.). BAS has key components: peer review, scientific methodology, logical conclusions, reasonable inferences, statistical analysis, applicable context, and references (Alverson, 2000, *in* Natural Resources Consultants, 2000). By itself, a compendium of literature citations is not subject to peer review and does not reflect a scientific method. The document does not synthesize, make conclusions, or make inferences. The context for the collection of references is primarily forested lands. The compendium does not synthesize or draw conclusions based on the literature compiled for agricultural lands.

To better understand how this body of literature was used to arrive at the recommended agricultural buffer widths, we have read and summarized each of the 15 primary sources (Appendix A). Of the 15 bibliographies, six focus on general riparian science, five focus on forestry science, two involve permitting, and two involve agriculture. We estimate that less than 1 percent of the literature cited deals with agricultural data, and none of it is synthesized to develop buffer width recommendations for agriculture.

In addition to our review of the above compendium (Mankowski and Landino, *op. cit.*), we have obtained peer reviewed literature (consistent with BAS criteria) pertinent to the issue of buffer width and effectiveness on agricultural lands. In general, studies have shown that the fixed-width approach *is easier to enforce and administer, but often fails to provide for many ecological functions* (Castelle *et al.,* 1994). We summarize this information in Section 3. Our search was not exhaustive and if we missed important work, we hope that others familiar with the literature will bring it to our attention, as this is a Work In Progress.

2.4 Different Buffer Widths for Forest and Agriculture

It is important to recognize that riparian buffer widths suitable for mitigating the effects of timber harvest are not directly applicable quantitatively, or in many cases qualitatively, to agrarian activities in physically and biologically dissimilar environments. Arbitrary or uniform imposition of fixed-width riparian buffers on agricultural lands raises serious issues related to private property, economic impacts, and the most effective means of salmon habitat recovery and protection.

In developing this report, we examined the scientific literature on riparian buffers and found that: (1) the use of buffer prescriptions for timber exaggerates the conditions that apply to agriculture for a variety of ecological needs, impact assessment, or salmon protection, (2) uniform prescriptions for wide buffers on every stream are generally based on the mistaken assumption that all or even most agricultural streams are currently unsuitable for salmonids, and that, if impaired, are primarily caused by agricultural activities, and (3) that impairment of agricultural streams is primarily from loss of large woody debris, an assumption not verified by data on agricultural lands. Recruitment of LWD requires the widest buffers according to forest science (*cf*. Knutson and Naef, 1997).

We have examined numerous peer-reviewed studies on stream buffers and found that buffer widths developed to mitigate impacts of timber harvest may be hundreds of feet wider than required for agriculture when the purpose is to reduce nutrients, chemicals, sediment, and erosion, or to provide shade (see Section 3). The literature we reviewed demonstrates that buffers of 5 to 30 meters function adequately for water filtration, sediment reduction, animal exclusion, shade, nutrient removal and bank stabilization for conditions reported on agricultural lands.

Recommendations for buffers wider than 100 feet on each side of streams are primarily consistent with accommodation for LWD recruitment and for terrestrial wildlife, not for restoration of salmon streams on agricultural lands (*cf*. Appendix C in Knutson and Naef, 1997). Although wildlife corridors may be worthy conservation objectives, it is not the legal or management objective of agriculture. The literature also shows that LWD is primarily a product and function of large trees from coniferous forests, rather than valley bottoms. LWD from upland forests eventually reaches valley bottoms via hydraulic transport and may contribute as much as 50 percent of the woody debris there (*op.cit*.). For approximately 20 years, fishery management practices removed large woody debris from forested streams—a legacy that is best corrected by regeneration of upland forests and anthropogenic habitat improvement measures during the regeneration process.

2.5 Alternatives to Mandatory, Fixed-Width Riparian Buffers

The general value of riparian vegetation for fish, wildlife, and water quality is well established in the literature and is not disputed by our findings. The goal of this study is not to determine if buffers are good for these purposes. It is to determine whether it is necessary to broadly prescribe buffers of a specific width on agricultural lands to restore habitat for listed fish. The proposals to develop buffer widths to fully establish riparian habitat preserves or wilderness corridors (Knutsen and Naef, 1997) probably go beyond the needs of salmon habitat restoration. A scientific basis for salmon habitat restoration will match form to function: that is, buffers will be one tool to restore identified habitat deficiencies along specific stream reaches when preferred alternatives are ineffective. In some cases, riparian buffers will be the preferred alternative, but the width of each riparian buffer should be established to meet site-specific criteria based on BAS that is specific to agricultural lands.

The scientific literature and historical experience indicate that agricultural impacts can be effectively managed using a variety of tools known as Best Management Practices. Through assistance of the National Resource Conservation Service (NRCS), the vast majority of agricultural lands have BMPs in place that can either prevent or reduce major impacts, and BMPs can provide immediate benefits through direct intervention. For example, if bank erosion is occurring, a direct solution BMP will stabilize the bank. This may be through a variety of approaches including buffers, but may also include other techniques. As another example, if nutrient overloading is a concern, the first action should be to eliminate direct irrigation runoff or animal waste input to the stream. If that is only partially effective, then secondary actions, including use of buffers or exclusion devices, may be needed. BMPs can include riparian buffers, vegetation strips, and other land set-asides based on site-specific requirements. The width, importance, and form of a riparian buffer can be established on a case-by-case basis where site-specific data demonstrate that it is the appropriate BMP. These types of actions typically occur through voluntary collaboration of farmers with NRCS scientists and gain cost shared support via federal, state, and local programs.

2.6 Report Contents

Under the Endangered Species Act and Washington's Growth Management Act, county and city planning must give "special consideration" to conservation or protection measures to preserve or enhance anadromous fisheries for listed species and to preserve or enhance "critical areas" based on the Best Available Science. BAS guidelines include:

- Entities should consult with qualified scientific experts.
- Entities may use information that resources agencies have determined represent BAS.
- Other peer-reviewed literature is an important source of BAS.

Reports and documents referenced in Section 3 have met the criteria for BAS as presented above. We expect the findings of this report and references herein will be useful to those local governments that are establishing the need for riparian buffers to protect salmonids and critical areas.

Our review of the literature confirms that riparian habitat is valuable to fish and wildlife. The report explores the appropriate role and width of riparian buffers on agricultural lands. Our findings suggest that: (1) performance and effectiveness of buffers on agricultural land is highly variable and both site-specific and function-specific, (2) the few studies that evaluate buffer widths experimentally have shown improved ecological function with buffers between 5 and 30 meters wide, and (3) a quantitative approach to buffer width is inadvisable without site-specific data (*e.g.,* O'Connell *et al*., 1993; *In*, Knutsen and Naef, 1997; Metro, 2002).

In Section 3, we review the science associated with riparian buffers, with an emphasis on buffers as a management tool for controlling non-point source impacts to agricultural streams. We review applicability of the six ecological functions of riparian buffers as developed by the Forest Ecosystem Management Assessment Team (FEMAT; Appendix A.3). Section 4 discusses economics of buffers, in terms of both land value and revenue impacts. Section 5 lists the peer-reviewed references and other sources of information we used in this review. The appendices provide our review of the literature and regulatory requirements provided by State and Federal agencies to the Ag Caucus.

Section 3 – Science of Riparian Buffers on Agricultural Lands

3.1 Background

In response to a request by the Ag Caucus, the NMFS and WDFW provided an extensive bibliography of research papers related to riparian ecosystem functions (Mankowski and Landino, 2001). NMFS and WDFW indicated that this body of literature provides the basis for ongoing initiatives to protect riparian functions—initiatives that are the focus of Habitat Conservation Plans, the Forest and Fish Report, Tri-County Conservation Planning, and Endangered Species Act Section 7 Consultations. The 15 primary documents contained in the bibliographic compendium (Appendix A) range from studies that are directly applicable to riparian buffers in agricultural areas (USDA:National Resource Conservation Service, 1997), to those that are relevant but clearly focused on forest management and defining properly functioning conditions within riparian areas (FEMAT, 1993; NMFS, 1996). Together, these studies represent a comprehensive body of information on the ecology and major functions of riparian forests: provision of large wood, shade as it affects stream temperature and microclimate, streambank stability, litter-fall, sediment filtration, and floodplain processes (Naiman *et al*., 1992; Spence, *et al*., 1996; FEMAT, 1993; Chamberlin *et al*., 1991; Sullivan *et al*., 1987; CH2M HILL, 1999).

While the general function of riparian zones and needs of aquatic and terrestrial biota that depend on them are well established, there is considerable debate about the widths of riparian buffers needed to restore and/or ensure properly functioning conditions (PFCs) in salmon bearing streams. Given the regulatory climate that frames much of this discussion, the use of PFC as defined by NMFS is an appropriate gage of the health of agricultural streams. As described in the Citizen's Guide to the 4(d) Rules (NMFS, 2000), the NMFS defines PFC as the sustained presence of natural habitat-forming processes (*e.g.*, hydraulic runoff, bedload transport, channel migration, riparian vegetation succession) that are necessary for the long-term survival and recovery of the species (NMFS, 1999). Thus, PFCs constitute a species' habitat-based biological requirements—the essential physical features that support spawning, incubation, rearing, feeding, sheltering, migration, and other behaviors. Such features include adequate instream flow, appropriate water temperature, loose gravel for spawning, unimpeded fish passage, deep pools, and abundant large tree trunks and root wads.

Issues associated with buffer widths have recently come before the Western Washington Growth Management Hearings Board (WWGMHB) for several Washington counties, including Island

and Skagit Counties, where riparian buffers and the Best Available Science underlying their adoption have been challenged. Literature reviewed in this section focuses on the efficacy and need for buffers to achieve ecological function on agricultural lands. Specifically, we address transport of unwanted materials into the stream, transport of needed materials into the stream, shade and temperature, physical habitat, and its protection and enhancement. The section concludes with remarks on the values of fixed versus variable buffers and research needs for better data and experimental design on agricultural lands.

3.2 Origins of Recommendations: Forest-Based FEMAT Curves

The majority of the literature now relied on for determining buffer widths in Washington State can be traced to models developed by the Forest Ecosystem Management Assessment Team (FEMAT, 1993) in connection with development of the Northwest Forest Plan (Appendix A.3). Geographically, FEMAT criteria were developed to determine required widths of riparian reserves for streams on federal lands within the range of the northern spotted owl. These models, Riparian Process Effectiveness Curves, are a series of functions that relate buffer width to a specific ecological function considered critical to aquatic and riparian habitat preservation on lands being harvested for timber. The functions are plotted as a two-dimensional relationship of distance from the stream and effectiveness with respect to the various functions provided by the riparian zone. The curves were developed from a number of studies showing decreasing effects of riparian vegetation on streams with increasing distance from the streambank (VanSickle and Gregory, 1990; McDade *et al*., 1990; Beschta *et al*., 1987). As noted above, these functions include large woody debris recruitment, shade, streambank stability, litter-fall, sediment filtration, and floodplain processes.

Riparian reserve widths recommended in the FEMAT Report are based on multiples of a site-potential tree height (SPTH), defined as “the average maximum height of the tallest dominant trees (200 years or older) for a given site class.” The distance is measured from the edge of the area within which a stream naturally migrates (the channel migration zone) or a prescribed slope distance, whichever is greater. A report prepared for the NMFS (Spence *et al*., 1996), known as the ManTech Report, makes similar recommendations for the design of Habitat Conservation Plans on non-federal lands in the same areas. Reserve widths may be adjusted based on watershed analysis to meet Aquatic Conservation Strategy objectives (FEMAT, 1993). Since the FEMAT curves were developed as a product of the Northwest Forest Plan, and were a key element of the Timber Fish and Wildlife Process that led to the Forest and Fish Report, they are naturally oriented to managed forested lands. Under Option 1 (maximum protection), the FEMAT prescribed widths on both sides of streams for all watersheds are:

- Fish-bearing streams - the larger of two site potential trees or 300 feet.
- Perennial non-fish-bearing streams - the larger of one site-potential tree or 150 feet.
- Intermittent streams - the larger of one site-potential tree or 100 feet.

For western and eastern Washington, the State's Forests and Fish Rules governing private and State lands require a riparian buffer on either side of a stream that may contain fish habitat. The required buffer extends to one SPTH from bankfull width or the edge of the channel migration zone (CMZ). The SPTH varies from 90 feet to 200 feet (27 m to 61 m) depending on the site class (V-I) location and whether fish are present. The riparian buffer is divided into three zones—the core zone, the inner zone, and the outer zone—which are further defined for east and west sides of the Cascades.

1. The west side core zone extends 50 feet (15 m) from bankfull width or the edge of the CMZ. No harvesting is allowed in this zone. The east side core zone is 30 feet (10 m).

2. The west side inner zone extends from the outer edge of the core zone to 67 percent of the SPTH for streams less than 10 feet (3 m) wide or 75 percent of the SPTH for streams greater than 10 feet (3 m) wide. Limited harvest is allowed in this zone only if the remaining number of trees, basal area, and proportion of conifer are sufficient to meet Desired Future Conditions (DFC) when the stand is 140 years old (WAC 222-30-021). The east side inner core zone would be 75 to 100 feet (25 m to 30 m), depending on stream width.

3. The outer zone for both the east and west side extends from the outer edge of the inner zone out to the SPTH. Harvest is allowed in this zone as long as 20 conifers per acre (49 per ha) over 12 inches (30 cm) in diameter are retained as leave trees. If the inner zone is harvested under Option 2, a basal area credit may be available that decreases the outer zone leave tree requirements to as low as 10 per acre (25 per ha).

The FEMAT report has been thoroughly independently reviewed. For forests, it is not clear that these multiple SPTH recommendations do not overstate the widths needed to meet proper functioning conditions where tree harvest is the impact (CH2M HILL, 1999). However, it is clear that retention of large wood and shade have been the dominant factors in determining buffer widths and management zones specified in the FEMAT report, as well as in the Washington Forest and Fish Report.

Agricultural impacts differ significantly from those due to timber harvest, and can be broadly classified as follows (from Knutson and Naef, 1997):

- Soil erosion and sedimentation
- Pesticides and fertilizers
- Animal wastes
- Irrigation/water withdrawal
- Grazing

A basic conclusion of this review is that, if the management focus is tied directly to agricultural impacts, the required width of riparian buffers will be substantially less than those recommended in forested ecosystems.

3.3 Performance of Buffers in Agricultural Areas

3.3.1 Introduction

Castelle *et al*. (1994), Wenger (1999), Platts (1991), and Castelle and Johnson (2000), review the scientific literature on ecological functions of riparian buffers, and discuss widths of buffers needed for various ecological functions. In general, these reviews, which collectively summarize hundreds of different studies of buffer effectiveness, found that relationships are non-linear such that the marginal benefit of increasing buffer width is greatest at low-width values and becomes progressively smaller at higher width.

Castelle and Johnson (2000) considered buffer effectiveness relative to six functions: three “sink” functions (streambank stabilization, sediment reduction, and chemical removal) followed by three “source” functions (Large Organic Debris (LOD) production, Particulate Organic Matter (POM) Production, and Shade Production for stream water temperature maintenance). Studies reviewed by Castelle and Johnson (2000) indicate that for five of the six functions considered, the effectiveness of riparian buffers increases with buffer width; however, most of the potential contributions of riparian vegetation to these functions are realized within the first 5 to 25 m (16 to 82 feet) from the streambank. Buffer widths of 5 to 25 m typically provide at least 50 percent of the potential effectiveness, and often 75 percent effectiveness or greater. Disproportionately wider buffers are needed to achieve greater effectiveness (i.e., the marginal benefit of making buffers wider declines rapidly as buffer widths increase beyond 5 to 25 m (16 to 82 feet) (Castelle and Johnson, 2000).

Based on a large body of literature reviewed by Castelle and Johnson (2000), the authors developed curves of effectiveness versus buffer width, similar to those developed for the FEMAT report. A summary of the literature for each ecological function of buffers follows.

3.3.2 Streambank Stabilization and Sediment Reduction

Castelle and Johnson (2000) summarized factors affecting streambank stability as a balance of forces, including soil properties such as moisture content and texture, erosive forces such as overland flow, and external factors such as compaction by vehicular traffic, wildlife, and livestock trampling. High moisture content enhances sediment transport rates by accelerating detachment of particles, thus increasing transport of adsorbed nutrients, bacteria, or other contaminants downslope (Henderson, 1986).

Interception of sediment and debris by vegetated buffers reduces velocity of overland flow, increasing infiltration of soil particles through leaf litter, and retention via metabolism by microbes and plant uptake (Lee *et al*., 1999). These factors counter the transport of sediment-bound contaminants in surface flow. Roots maintain soil structure, physically restraining otherwise erodible soil, and helping to maintain sheet flow by resisting formation of channels (Castelle and Johnson, 2000). Zimmerman, Goodlett, and Comer (1967) observed that the width-to-depth ratio of a stream was three times greater in forested reaches (ratio of 6.1) than in meadow reaches (ratio of 2.0), and attributed this difference to the extensive root systems of herbaceous plants in meadows that have a stabilizing influence on the stream channel.

Roots of woody plants may also play an important role in streambank stabilization, particularly deep-rooted trees and shrubs. Deep roots can penetrate the soil profile and become anchored in more stable strata, such as weathered or fractured bedrock. It has also been suggested that streambank undercutting is possible because streambank collapse is prevented or at least delayed by roots (Richards, 1977). Note that other vegetative factors, such as the presence of large woody debris, may have the effect of armoring streambanks and increasing streambank stability.

Research conducted by Tufekcioglu *et al*. (2001) indicates that vegetative buffers had significantly higher soil respiration rates than did adjacent crop fields, suggesting higher levels of biological activity within the buffers. This factor has implications not only for streambank stabilization but also for the presence of added organic matter, providing better conditions for nutrient sequestration within the riparian buffers (Tufekcioglu *et al*., 1999).

Waldron and Dakessian's (1982) examination of the influence of plant roots on soil stability included seven grass species, two legumes, and two trees. These investigators measured direct shear resistance in packed soil columns. Generally, their findings support the observations of Zimmerman, Goodlett, and Comer (1967) and others, in that herbaceous roots were found to provide significant soil stabilization. However, they noted that the roots of all species examined increased soil strength to varying degrees. Specifically, many of the grass species planted in early autumn produced nearly a three-fold increase in soil shear resistance by late spring, less than eight months after planting. Tree roots (*Pinus ponderosa* and *Quercus agrifolia*) were also found to provide soil shear resistance of this magnitude, but only after tree saplings were 3 to nearly 5 years old.

Kleinfelder *et al*. (1992) examined streambank collapse due to compressive forces, such as those imparted by livestock trampling. They also noted that the important relationship between root-length density and compressive strength of non-cohesive soils was non-linear, with substantial increases in strength occurring from moderately dense root systems–about 2 mm/mm^3. Beyond that point, increased root-length density increased soil strength by progressively smaller amounts, reaching an apparent asymptote at approximately 50 kPa. They also found that the roots of different plants provided varying amounts of compressive soil strength. In their study, *Carex nebrascensis* imparted the greatest compressive soil strength. In un-incised headwater streams in eastern Oregon, Toledo (2001) found significantly greater root biomass and structural integrity at the immediate margins of the streambank than in incised channels.

Balsky *et al*. (1999), Ehrhart and Hansen (1997), and Platts (1991) summarize much of the technical literature describing the impacts of livestock on riparian ecosystems. A review of technical sources that assess the impacts of grazing on riparian habitat and salmonid populations uncovered a range of observations surrounding the magnitude of impacts. What is apparent is that grazing impacts are highly dependent on site conditions and the types of grazing management practices that are employed.

Concern for grazing impacts has led researchers and managers to identify grazing strategies that can be compatible with healthy riparian ecosystems (Ehrhart and Hansen, 1997; Mosley *et al*., 1999). Several published reviews discuss strategies for riparian grazing that have been found to be effective in maintaining riparian health. Some strategies include the use of riparian buffers and more intensified land and grazing management.

In his review of livestock grazing strategies, Platts (1991) rated corridor fencing as a nine on a scale of one to ten with one being poorly compatible with fishery needs and ten being highly compatible. Corridor fencing results in good to excellent streambank stability, excellent brushy species composition, good to excellent seasonal plant new growth, and excellent stream riparian rehabilitation. However, there is little literature that scientifically assesses the width of the fenced corridor needed to provide for healthy riparian habitat in rangeland (Mosley *et al*., 1999).

Relative to fecal coliform impacts on water quality, minimal buffer zones may be adequate. In the literature review done by Mosley *et al*. (1999), they cite Doyle *et al*. (1975) and Oskendahl (1997) for their recommendation that a buffer strip of 12.5 feet on each side of a stream may be adequate to protect water quality from coliform bacteria and effectively filter nutrients. Jefferson County Conservation District (2001) actually demonstrated these improvements in western Washington.

A number of measures other than corridor fencing have been evaluated that can improve riparian conditions on rangelands. Ehrhart and Hansen (1997) investigated cattle grazing practices that were compatible with healthy riparian ecosystems in Montana. They did this by inventorying a number of pastures that had healthy riparian areas and then interviewing the landowner or manager to determine how cattle were managed in that pasture. They found that what operators did to encourage livestock not to loiter in the riparian zone, while in a pasture, was more important than either season of use or length of time in the pasture per se. With proper management under specific conditions, many pastures containing a variety of riparian types may be grazed in various seasons and for various periods of time without adversely impacting the health of the riparian area (Ehrhart and Hansen, 1997).

One quantifiable factor noted by Ehrhart and Hansen (1997) was that many of the healthy riparian pastures also contained alternate water sources off the stream. The second theme noted by Ehrhart and Hansen (1997) was a high degree of operator involvement. All the operators were actively involved in managing their land and had a keen interest in the condition and trend of their riparian areas. Managers willing to modify management practices and conduct monitoring, whether formal or informal, was a component to the successful maintenance of riparian areas with livestock.

The conclusions of Ehrhart and Hansen (1997) were that riparian grazing might be incorporated into each of the traditional grazing systems, as long as the condition of the riparian zone itself remains of primary concern. They concluded that management, not the grazing system, is the key.

Mosley *et al* (1999) conducted a literature review of the management of cattle grazing in riparian areas. Like Ehrhart and Hansen (1997), they also concluded that there is not one particular grazing system that can be applied in all situations. They recommend that grazing plans be site-specific and based upon the best research available. They have provided several suggestions for a riparian grazing plan:

- Determine the tolerance of a riparian site to grazing and then limit the grazing periods to avoid exceeding the critical period length.
- To increase vegetative density, increase rotational scheduling of cattle grazing.
- To graze a site more than once per growing season, moisture and temperature conditions should be conductive to vegetative re-growth. Grazing more often and for shorter periods is preferable to fewer and longer grazing periods.
- Adjusting timing, frequency, and intensity of grazing in individual pasture units is more important than adopting a formalized grazing system.
- Prevent cattle from congregating near surface waters. Fencing, supplemental feeding, alternative water sources, and herding work best.
- Locate the edges of features where cattle congregate—such as salt grounds, water developments, and winter-feeding grounds—away from surface waters and buffer strips.
- Maintain at least 50 percent protective ground cover along streambanks. Vegetation buffer strips should usually not be necessary to protect banks and reduce impacts from

cattle urine and feces unless cattle congregate near surface waters to the point that protective ground cover is less than 50 percent.

Mosley *et al*. (1999) concluded that the impact of cattle grazing on riparian ecosystems depends entirely on how the grazing is managed. The important variables are timing, frequency, and intensity of grazing. Each situation is unique and requires its own creative, locally tailored solution. The best way to know whether a particular management strategy is suitable for a particular site at a specific point in time is to implement the strategy, and then monitor its effectiveness and adjust the practice as needed.

When buffer width is graphed against sediment removal from multiple peer-reviewed studies, it is apparent that little additional benefit is gained beyond 15 m (49 feet), and maximum benefits at much less than 15 meters (Figure 3.1). Effective sediment removal in an agricultural setting was illustrated by a study in which various treatments (buffer widths) were matched by controls (Ghaffarzadeh, Robinson, and Cruse, 1992). Using grass filter strips ranging from 0 to 18.3 m (0 to 60 feet) on 7 and 12 percent slopes, these authors found no difference in sediment removal on either slope beyond 9.1 meters (less than 30 feet), where 85 percent of the sediment was removed. Further, there was no difference in sediment removal between the two slope angles beyond 3.1 m (10.2 feet). The sedge *Carex nebrascensis* imparted the greatest compressive soil strength of various species used in this study. In un-incised headwater streams in eastern Oregon, Toledo (2001) found significantly greater root biomass and structural integrity at the immediate margins of the streambank than in incised channels.

According to a review by Desbonnet *et al*. (1994), the most efficient width of vegetated buffers for sediment removal is 25 m (82 feet). For total suspended solids (TSS), buffer widths need to increase by a factor of 3.0 for a 10 percent increase in removal efficiency, and greatest efficiency is provided by 60-m (197-foot) buffers. Note that this review was conducted for riparian buffers in the coastal zone and may not be directly applicable to inland areas of the Pacific Northwest.

Wenger (1999) points out that the Desbonnet (*op.cit*.) review was based on a composite of data from studies conducted with various methods at different locations. Studies that compare multiple buffer widths in the same location and the same study conditions are more illuminating. Figure 3-2 (from Wenger, 1999) graphically depicts the results of several studies of this type. Although percent removal of TSS increases with buffer width in all these studies, most of the results indicate that buffers between 10 and 20 m (33 and 66 feet) remove between 80 percent and 90 percent of the TSS.

Wenger (1999) noted that most of the studies described above were short term. There is evidence from long-term analysis that wider buffers are necessary to maintain sediment control. Long-term studies by Lowrance *et al*. (1988) and Cooper *et al*. (1987) indicate that, although riparian zones are efficient sediment traps, the width required for long-term retention may be substantially more than is indicated by short-term experiments. Buffers of 30 m to 100 m (98 to 328 feet) or more might be necessary for long-term protection (Wenger, 1999). Overall, Wenger (1999) concluded that a 30-m (98-foot) buffer is sufficiently wide to trap sediments under most circumstances, and a 9-m (30-foot) wide buffer would be the absolute minimum width.

Curves fit to studies included in Figure 3-2 illustrate that buffer widths of 7 m to 60 m (23 to 197 feet) all produce a similar effect of arresting about 80 percent of sediment, and that little additional benefit is gained beyond approximately 7 m (23 feet). Another observation is that of the various types of landscapes, the agricultural studies showed that narrow buffers of 7 m and 15 m (23 to 49 feet) were as effective as buffers up to 8 times wider on other types of habitats. The inclusion of the agricultural studies completely changes the shape of buffer-width benefit curves in agricultural settings and conclusions about the effectiveness of narrow buffers. Again, where agricultural data are available, considerably different conclusions are reached than if only forest data are used.

3.3.3 Water Quality Protection

Protection/maintenance of water quality is arguably the most important function for buffers in agricultural areas. Riparian buffers, (or vegetated filter strips (VFS)), protect stream water quality by physical entrapment of chemicals bound to sediment particles and uptake by plants (nutrients, pesticides, herbicides, other cations and anions).

Wenger (1999) cites several studies that document removal of a large proportion of pollutants in the first few meters of a riparian buffer (Dillaha, 1988; Dillaha 1989; Castelle and Johnson, 2000) (Figure 3.3). These data include an obvious outlier, without which it could be concluded that no further increases in removal occurs beyond approximately 15 m (49 feet). The steepness of the effectiveness/width curve can be attributed to uptake of dissolved nutrients, coupled with rapid removal of sediment-bound pollutants within the first few meters, such that 10 meters (30 feet) of buffering is adequate to remove up to 90 percent of chemical runoff. Lowrance (*op. cit.*) noted that field studies of nitrate removal show that much of the nitrate is removed in the first few yards of a 90- to 100-foot buffer. These studies suggest that buffers much narrower than 10 meters may be quite functional. Some additional peer reviewed literature further elucidate buffer width and chemical removal (from Wenger 1999):

- Lowrance *et al*., 1997, *in* Isenhart examined changes in pesticide concentrations crossing a 50-m (164-ft) wide buffer in the Georgia coastal plain. Atrazine and Alachlor were reduced from 34 *u*g/L and 9.1 *u*g/L, to less than 1 *u*g/L.

- Hatfield *et al*. (1995) found that grassed filter strips of 12.2 m and 24.4 m (40.0 and 80.1 feet) removed 10 to 40 percent of the atrazine, cyanazine, and metolachlor passing across them.
- Arora *et al*. (1996) found that a 20-m (66-ft) wide riparian buffers of 3 percent slope retained 80 – 100 percent of the herbicides (atrazine, metolachlor, and cyanazine) that entered during storm events. The variation was related to the amount of runoff.
- Neary *et al*. (1993) concluded that, generally, buffers of 15 m (49 feet) or larger are effective in minimizing pesticide residue concentration of stream flow.

In a review of BAS associated with riparian buffers to protect in-stream water quality and fish habitat, Castelle (2000) provided the Island County Board of Commissioners with a summary of literature focusing on buffer widths needed for proper functioning conditions in agricultural riparian buffers. The Island County Board of Commissioners had specifically requested a review of BAS supporting an 8-m (25-ft) riparian buffer. Pertinent findings of this review include:

- Ahola (1990) recommend 2- to 10-m (7 to 33 feet) buffers for stream habitat protection.
- Dillaha *et al*. (1989) found that 4.6-m (15-ft) vegetated filter strips removed 70 percent of suspended solids, 61 percent of phosphorus, and 54 percent of nitrogen.
- Doyle *et al*. (1975) reported 95 percent nitrogen removal and 99 percent phosphorus removal in 3.8-m (12-ft) buffers, and recommended 7.6-m (25-ft) forested buffers to protect water quality from animal wastes.
- Doyle *et al*. (1977) found substantial removal of nitrogen, phosphorus, potassium, and fecal bacteria in 3.8-m (12-ft) forested buffers and in 4-m (13-ft) grassy buffers.
- Ghaffarzadeh *et al*. (1992) reported no further improvement in vegetated filter strip efficiency in removing sediments beyond 9.1 m (30 feet).
- Hubbard and Lowrance (1992) stated that nitrate had "very little impact" on riparian systems after passing through a 7-m (23-ft) forested buffer.
- Madison *et al*. (1992) reported 90 percent removal of nitrogen and phosphorus by a 4.6-m (15-ft) grassy buffer.
- Neibling and Alberts (1979) found 82 percent sediment removal in 2.4-m (8-ft) buffers, and 90 percent sediment removal in 4.6-m (15-ft) buffers.
- Reneau and Pettry (1976) demonstrated 94 percent removal of phosphorus in shallow groundwater after a distance of 3 m (10 feet).
- Xu *et al*. (1992) found similarly high nutrient removal rates, nearly 100 percent removal of nitrate-nitrogen in a 10-m (33-ft) mixed herbaceous/forested buffer.
- Fisher (1999) and Fisher *et al*. (1999) point out that recommended widths for ecological concerns in buffer strips typically are much wider than those recommended for water quality concerns.

In addition to the above, Mendez and Mostaghimi (1999) found that 8.5-m (28-ft) riparian buffers reduced sediment, nitrate, dissolved ammonium, and total Kjeldahl nitrogen yields significantly with mean reductions of 90, 77, 85, and 82 percent, respectively. These authors also reviewed the effectiveness of 4.3-m (14-ft) filters and found no significant differences in pollutant trapping efficiencies of the 8.5- and 4.3-m (27.9- and 14.1-ft) buffer widths.

Addy *et al*. (1999) concluded that riparian zones composed of a mix of forested and mowed vegetation may remove substantial amounts of groundwater nitrate nitrogen. The authors qualify this conclusion with a note that uncertainty exists regarding the site characteristics that promote substantial groundwater nitrate nitrogen removal in riparian zones and the influence of different types of riparian vegetation cover on groundwater nitrate nitrogen removal.

Corley *et al*. (1999) found that a 10-m (30-ft) wide riparian buffer zone was an efficient filter of inorganic nitrogen and inorganic phosphorus in a montane riparian community as about 84 percent nitrate nitrogen and 79 percent phosphate phosphorus were removed from the applied treatment. No consistent differences were found among specific vegetation height treatments or communities in the removal of N and P nutrients.

For concentrated runoff, *e.g.*, feedlot effluent, buffer widths may need to be considerably wider than for general protection from non-point runoff. Dickey and Vanderholm (1981) reported that flow lengths of 305 m (1,001 feet) were required to achieve reductions of 60 percent of nitrate and chemical oxygen demand (COD), and only 16 percent for phosphorus. Runoff from a feedlot of 450 cattle was sent through a fescue- and alfalfa-lined, serpentine channel with a 2 percent slope. A similar test using overland, rather than channelized flow filters, required much shorter distances [90 m (295 feet)] to achieve 70 percent reduction in nitrate and total solids.

Chimacum Creek watershed in western Washington (Jefferson County Conservation District, 2001) improved fecal coliform counts and other water quality parameters via implementation of improved livestock management on pastures, and on riparian area fencing. The fencing, constructed since 1988 along 8 miles of stream, mostly protects the bankfull width of the stream creating a set-back zone of about 8 to 20 feet (personal communication, Al Lathum, JCCD, 2002). The reported fecal coliform bacteria counts dropped from over 400 FC/100 mL (GMV) to under 100 FC/100 mL. Fecal coliform concentrations in the Chimacum Creek watershed were lower in 2000 than at any other time since monitoring began in 1988 (Jefferson County Conservation District, 2001).

Subsurface removal of nutrients in groundwater within the riparian zone may be an important mechanism in addition to buffer widths. Removal rates in groundwater are dependent on soil properties and water table height, and increase with decreasing distance to the stream (Simmons *et al*., 1992). Groffman *et al*. (1996) concluded that although measured groundwater denitrification rates were lower than surface rates, they may be high enough to create a significant sink for nitrate due to much lower flow rates, and could remove large percentages of incoming nitrogen loading.

While studies of nutrient reduction by riparian buffers are common in the literature, effects on herbicide transport have received relatively little study. Lowrance *et al*. (1997) reported that rates of herbicide reduction were greater in a grass strip immediately adjacent to the application zone than in an intermediate area of planted pines or in a zone of hardwoods closest to the stream channel (all three zones totaled 38 meters) [125 feet]) in width. Concentration reduction was greatest per meter of flow length in the grass buffer adjacent to the application zone.

3.3.4 Shade Protection

Riparian vegetation can directly affect stream temperature by blocking or reflecting solar radiation and reducing stream heating (IMST, 2000), thus helping to maintain ambient (incoming) water temperatures. The biological and physical values of shade to aquatic systems in forested ecosystems are well established (Beschta *et al*., 1987; Patton, 1973; Brown and Krygier, 1970; Brown, 1969; Brett, 1973). The value to terrestrial (air) temperatures is less clear. Dong *et al.* (1998) found that forest buffers provided minimal protection for stream air temperatures during mid-summer and that buffer width was not a significant variable in predicting stream air temperatures.

Thermal models of natural streams demonstrate that the best predictor of instream temperatures at any given point on a stream is the input temperature immediately upstream of the location in question (see Knutson and Naef, 1997, for a discussion and references). Thus, the role of buffers with respect to shade provision on agricultural lands is to reduce warming of inflow temperatures originating at the transition zone of the forested/mountainous areas and lowland valleys. The distinction between reduced heating of streams and actual cooling is important given that shade can, at best, maintain inflow temperatures by reducing incident radiation falling onto the stream surface, thus reducing natural warming. Heat transfer in streams is governed a number of factors, but largely by radiation and evaporation (*cf.* Oregon Department of Environmental Quality, 2000a, 2000b, 2001; and Washington Department of Ecology, 2002). In general, more extensive riparian vegetation ameliorates solar heating and maintains ambient water temperatures, although the influence of riparian shade on water temperature declines as streams widen in downstream reaches (IMST 2002).

Cascade mountain streams are generally between 40 and 50°F because groundwater and surface waters are thermally shielded from solar radiation by trees, snow and/or rocky soils. When forested systems are removed, surface water and snowmelt are released in greater volumes over a shorter time. This leads to higher peak flows, and greater ratio of surface to groundwater, thus increasing stream temperatures. Many thermal problems in agricultural basins can be partially traced to hydrological changes in upland basins due to logging (*cf.* Knutson and Naef, 1997).

Castelle and Johnson (2000) reviewed a study by Steinblums *et al*. (1984) in which the effectiveness of 40 streamside buffer strips were assessed in the Cascade Mountains of western Oregon. These authors define buffer strip effectiveness in terms of angular canopy density (ACD). ACD effectively integrates spatial factors such as stream width, tree height, and canopy density for a given site. The relationship of ACD to buffer strip width was curvilinear, yielding ACD values of 17 and 73 percent, respectively, for buffer widths of 6 and 31 m (20 and 102 feet). They also concluded that 90 percent of the maximum ACD could be obtained with a 17-m (56-ft) buffer strip.

A summary of findings of several studies (*in* Castelle, 2000) indicate that the asymptote of effectiveness of buffers with respect to shade provision is approximately 10 m (33 feet), beyond which little additional benefit is gained (Figure 3.4). Osborne and Kovacic (1993 *In* Wenger, 1999) report similar findings, and conclude that buffer widths of 10 to 30 m (33 to 99 feet) can effectively maintain stream temperatures. The Oregon Forest Industries Council (OFIC) commissioned a review study of the scientific evidence supporting the FEMAT riparian shade effectiveness curve. The resulting 1999 report found that neither the scientific source nor the technical basis of the FEMAT shade curves could be independently verified. In addition, the data and curves from the FEMAT-referenced studies did not fit the published FEMAT shade relationship. The same study also found empirical data that indicated that the FEMAT curve underestimates the shade contribution from riparian vegetation. The relative ability of shade to reduce stream warming depends on many factors, such as quality of shade, angle of sun, degree of cloud cover, leaf angle, aspect and orientation of watershed, time of year, stream volume, volume of subsurface flows, width and depth of water column, and height and density of vegetation (IMST, 2002).

In summary, thermal modeling has shown that stream temperature in a given location is primarily influenced by its boundary condition, or input temperature. Next, its future temperature is a function of the net energy that is exchanged at the surface; thus, the surface-to-volume ratio (width-to-depth ratio) is important. Aspect of the stream, stream width, surface-to-volume ratio of the stream, and the height of the natural vegetation are all factors that determine the thermal benefits of shade to a particular reach. However, review of the literature indicates that buffer effectiveness for shade protection is near 80 percent at approximately 10 m (33 feet), and that substantially wider buffers are needed to achieve relatively little additional benefit. This finding is supported by Wenger (1999) who reported that, to maintain stream temperatures, riparian buffers must be at least 10 meters (30 feet) wide, forested, and continuous along the stream channel.

3.3.5 Large Woody Debris

Large woody debris (LWD) is stems, branches, and roots greater than 10 cm in diameter, and are an important structural component affecting the behavior and morphology of small forested streams (Lisle, 1986). LWD improves both quality and quantity of fish habitat by varying stream velocity and depth, providing habitat with lower risk of predation (Harvey *et al*., 1999; Lisle, 1986). In smaller channels, LWD can stabilize landslide debris, store sediment, and prevent gully formation. In larger channels, LWD can trigger accumulation of spawning gravels, and create backwaters and pools (Reid and Hilton, 1998). Many of the effects of LWD on channel processes can be locally counteractive, but globally beneficial—for example, flow around LWD can scour away local gravel, but slow velocities enough to promote gravel deposition over a wider area (Lisle, 1995).

From 1950 to 1970, large woody debris was considered harmful to salmon and was purposely removed from streams (Knutson and Naef, 1997). However, research conducted over the last 20 years has shown that LWD is a critical component of aquatic habitat, and to headwater streams in particular. Sedell and Beschta (1991) summarize six functions of LWD: (1) creating and maintaining pools, (2) causing local reductions in stream velocities that serve as foraging sites for fish feeding on drifting food items, (3) forming eddies where food organisms are concentrated, (4) supplying protection from predators, (5) providing shelter during winter high flows, and (6) trapping and storing organic inputs from streamside forests, enabling them to be processed biologically.

The needed buffer width to provide adequate LWD from forests is controversial, given economic implications and the scientific uncertainty regarding needs of listed fish (Reid and Hilton, 1998). FEMAT (1993, Appendix A.3) developed models predicting effectiveness of forest buffers in providing LWD. However, these models assumed random tree fall (i.e., fall direction was independent of slope), a factor that has led to criticism of the FEMAT models (CH2M HILL, 2000).

In their critique of the FEMAT model curves, CH2M HILL (*op. cit.*) discusses factors that cause modeled data to depart from empirical data with source distance relationships. Factors such as variability in tree height, degree of bank erosion, and propensity of trees to lean down-slope cause the distance to effectiveness curves to shift toward the streambank, i.e., a narrower buffer can produce the same effectiveness as a wider (modeled) buffer. However, the LWD curves shown in the FEMAT report are based on modeled data, and rise slower, resulting in wider predicted buffers (CH2M HILL *op. cit.*).

Empirical data reported by McDade (1990, *in* CH2M HILL, 1999) indicate that 70 percent of LWD originated within 20 m (66 feet), and 100 percent within 61 m (200 feet). Murphy and

Koski (1989), in studying input and depletion of woody debris in Alaskan streams, found that for streams that are 8 to 30 m (27 to 98 feet) in width, 99 percent of identified sources of woody debris were within 30 m (98 feet) of the streambank. Nearly half of the woody debris came from trees that stood on the lower bank [less than l m (3 feet) away], and 95 percent was from trees within 20 m (66 feet) of the stream. They also noted that distances to the source of woody debris differed between channel types (alluvial or non-alluvial). On alluvial soils, these authors found that more than half (55 percent) of LWD was delivered by bank erosion (Castelle and Johnson, 2000; CH2M HILL *op. cit.*). Reid and Hilton (1998) found that 96 percent of potential woody debris sources occur within a single-tree height in a 50- to 60-m (164- to 197-ft) tall, second growth redwood forest.

Van Sickle and Gregory (1990) report that the decrease in the amounts of *in situ* LWD in larger streams is also due to the relative importance of transport and input of these systems. A model they produced shows that the number of trees contributed is independent of stream width, i.e., identical riparian stands along a small stream and a large river may contribute the same number of LWD pieces per unit channel length. The decline in the number of pieces of resident LWD in large streams was due to the greater transport capacity of larger streams, rather than to changing LWD inputs.

The CH2M HILL study recommends that the LWD curves be re-constructed to reflect LWD volume, not piece count, and that they be based on actual data as opposed to theoretical distributions. In addition, stand characteristics and erodibility of the channel (alluvial and non-alluvial) must be considered. Castelle and Johnson (2000) provide a graphical summary of distance-effectiveness relationships based on several of the field studies noted above (Figure 3.5). Their summary shows that 80 to 100 percent of the LWD originates within 20 to 30 m (66 to 98 feet) of the stream.

Bisson *et al*. (1987) showed that (evergreen) coniferous forests produce more durable and long lasting LWD than deciduous forests. This is probably a function of the size, quality and abundance of contributing wood. LWD in agricultural areas may owe as much as 50 percent of its content to upland forests as opposed to locally produced material (*cf.* Knutson and Naef, 1997). The functions of LWD in pool formation, velocity refugia, and spawning gravel retention are arguably more important in high gradient streams where unimpeded velocities may be unsuitable for salmonid habitat and life history functions.

The role and needs of LWD in lowland streams are less studied and demonstrated. In a recent research proposal to link salmonid fish abundance with land use and land cover in the agricultural Willamette Basin, Feist (2002) showed that LWD in this large agricultural watershed had only a 0.2 (not significant) correlation coefficient with riparian tree abundance along the banks of the Willamette River. Thus, presence of riparian forests is not a good predictor of

LWD in the Willamette Basin, nor, by extension, of salmonid abundance. It is likely that predictive models of LWD effectiveness and corresponding buffer requirements do not apply well in agricultural settings, although literature on this particular topic is severely lacking.

In summary, peer-reviewed studies on LWD suggest that: (1) LWD originates primarily from forests where velocities and erosive forces would otherwise limit habitat quality and quantity, (2) buffer widths to meet this need, even in forests, may be exaggerated in the forest ecosystem literature, and (3) the ecological function of LWD is likely a dominant factor in establishing wide buffer requirements in forests but its need in agricultural areas is not well demonstrated in the literature.

3.3.6 In-Stream Functions

Properly functioning streams have a diverse mixture of primary and secondary producers and consumers (i.e., attached algae, benthic macroinvertebrates, and fish) that are dependent on the riparian zone for a variety of biological and abiotic functions. However, few studies have looked at the adequacy of buffers and buffer widths needed to protect in-stream functions. In a statistically designed, paired watershed analysis, Whitworth and Martin (1990) assessed effectiveness of stream buffers in protecting and improving in-stream biological resources. This study demonstrated improved diversity in both fish and aquatic insect communities in filter-stripped (buffered) streams in Indiana and North Carolina. Buffer widths at the Indiana sites were 15 to 66 feet, and in North Carolina from 20 to 30 feet. The research was sponsored by the USEPA, entitled "Instream Benefits of the Conservation Reserve Program," and conducted in eight watersheds, two "treatment" sites with riparian buffers, and two control sites without buffers in each state. Streams were low gradient (< 1 percent), first or second order, and drained corn and soybean row-crop agriculture.

Density and species of insects were statistically greater at buffered sites in both states. Researchers considered the reduction of fine particulate organic material by stream buffers to be a key reason for healthier benthic communities at treatment sites. Diversity, but not density, of fish was also greater at all treatment sites; 21 fish species were collected at treatment sites, and 10 at control sites. Treatment sites had greater percentages of pollution-sensitive or intolerant fish species, in comparison to control sites. Average habitat quality, as measured using a modified Index of Biotic Integrity (IBI), was approximately 65 percent higher at treatment sites.

The USEPA study was specifically designed to assess the ability of buffers to improve the ecological integrity of streams draining agricultural lands. The results obtained for biological metrics, as opposed to those more temporally sensitive (water quality and sediment), clearly showed biological benefits obtained from buffers that are considerably narrower than those currently considered necessary for lowland streams in Washington (Knutsen and Naef, 1997).

3.4 Fixed *Versus* Variable Width Buffers

3.4.1 Science and Policies of Variable Buffers

In reviewing buffer zones for agricultural lands, USDA resource managers (USDA-NAC, 1997; USDA-NRCS, 2000) draw attention to two important tasks: (1) determine what site-specific benefits are needed and (2) determine the minimum acceptable buffer width. In evaluating need, the buffer zone should be designed to improve a specific function, such as improving stability or decreasing concentrations of coliform bacteria. The minimum acceptable width is one that provides acceptable levels of benefit at acceptable costs—the economics of the particular farmland involved cannot be ignored (a factor also stressed by USDA-NRDC, 2002). In effect, the recommendation for buffers is that they should be employed to target specific water quality problems, and their design should be based on marginal effectiveness and farm cost-effectiveness. To the extent that the objective is to stabilize banks or prevent sediment-attached contaminants from entering streams or water bodies, buffer zones of 25 to 30 feet can be used where slopes are less than 15 percent. This would be sufficient for many lowland areas where production agriculture occurs.

As noted by Castelle and Johnson (2000), riparian buffers may be prescribed using a mandated fixed-width, or allowing for variable widths based on local parameters. Fixed-width riparian buffers are more easily implemented and less costly to administer by resource agencies (Metro, 2000). However, this one-size-fits-all approach results in arbitrary buffer distances that may not always be appropriate to a particular site or management objective. Corner and Bassman (1993) concluded that although riparian buffer zones can be instrumental in protecting against non-point source pollution, their effectiveness is directly related to physical properties and the nature of management on the upland area. They recommend that a buffer zone width be calculated as a function of physical parameters (*e.g.*, slope, soil permeability, soil erodibility) and intensity of management practices, rather than as a designated fixed distance. A pertinent statement in the FEMAT (1993) report is that “[S]tructural components of stream habitat must not be used as management goals in and of themselves. No target management or threshold level for these habitat variables can be uniformly applied to all streams.” The team further concludes, “while this approach [fixed-width buffers] is appealing in its simplicity, it does not follow for natural variation among streams.”

IMST (1999) stated the following about the Oregon Department of Forestry’s fixed-width riparian buffer system: “Given the distinctive differences between stream functions based on size, we conclude it is scientifically sound to vary riparian widths with stream size” (p. 94). Although both fixed-width buffers and variable-width buffers may be related to stream size, variable-width buffers can be refined based on other stream attributes: soil type and erosion potential, vegetation (organic inputs, shading, large wood, wildlife habitat), landscape (topography, elevation, slope, stream structure and flow), and land-use characteristics (IMST, 1999). May and Horner (2000) stated simply that "…a one-size fits all buffer is not likely to work"

If a fixed-width riparian buffer must be used, an alternative approach bases buffer width on the *flood-prone area* of a stream or river, which can be described operationally as the area inundated when a stream floods to twice the bankfull depth (Rosgen 1996). However, this definition applies to small streams and does not work well in large or lowland rivers with wide floodplains that may or may not be feasibly protected (IMST, 2002).

No uniform prescription exists for riparian buffers, as evidenced the wide variety of widths and lengths now in use for various functions (Table 3.1 from Lowrance, *et al*., 2001). Six types are currently eligible for federal (CRP) cost sharing however, many others can be funded through state and local programs. In 2001, NRCS added a new type of in-field conservation buffer, sometimes called grass hedges. These are narrow strips of coarse grass 3 feet to 6 feet wide. Coarse stems withstand greater runoff rates without becoming submerged (Dabney, 2002, In Lowrance *et al*., 2001) and are thus effective in preventing gullies, and depositing soil in the field where it can further contribute to soil fertility and crop production. Thus buffers as narrow as 1 meter can be of value in agricultural landscapes. The list in Table 3.1 shows that most of the NRCS prescribed buffers on agricultural lands are as small as 6 meters to be effective.

3.4.2 Mandated versus Voluntary Programs

Bear Creek, Iowa, is a model agricultural restoration project being studied and managed by scientists at Iowa State University (Isenhart *et al*., 1998). The Bear Creek restoration project recognized early on that floodplains that are heavily used for agriculture and streams are part of a continuous ecosystem (National Resource Council (1992) *in* Isenhart *et. al.,* 1998). Restoration to pre-agricultural conditions is not the goal of the project because of the destruction of the enormous economic wealth of the agricultural system. Their goal is an ecologically functioning system that uses *voluntary participation* [italics added] and incorporates economic considerations into recommended actions. To quote Isenhart (*op.cit*.):

> *"The social acceptance of the riparian management model is assessed through the use of surveys, focus groups and one-on-one information exchange. A better understanding of landowner objectives and economic considerations has resulted in numerous variations of the model system. What initially began as just the buffer strip component of the system now includes the three other components: streambank stabilization, constructed wetlands and rotational grazing. This flexibility is designed*

> *to encourage adoptions of the management practices by satisfying the landowner goals and concerns as wells a fitting specific biogeophysical conditions of the site. For example, the buffer strip component of the model can be modified by using different species combinations and by varying the width of each zone. Although such variation in design may not be optimal for water quality or wildlife benefits, the flexibility is important if it means that a landowner is accepting the concept. After the landowner has had experience with a smaller system, he or she may be willing to increase the size and effectiveness of the buffer or add additional system components."* (Isenhart et al., 1998, p.332)

Elaborating further, the Iowa State University Team approach (IStART) shows:

> *"Technology transfer efforts are geared toward quickly getting the results and information into the hands of landowner and natural resource professionals. This is accomplished through on-site tours, field days, self-guided walking tours, videos and extension bulletins. Other methods of information disseminations include presentations at meetings of natural resource professionals, conservation groups, and local civic organizations, articles in local newspapers and trade publications and publications in refereed journals. Local ownership of the restoration effort is encouraged through the development of voluntary citizen action teams that assist in buffer strip establishment, water quality monitoring, and constructing of wildlife nesting boxes. Finally, training workshops are being organized for agricultural and natural resource professionals to help disseminate the information and validate results."* (Isenhart et al., 1998, p.332). The Iowa State University experience and demonstration program stresses voluntary adoption versus regulatory approaches of buffer strip installation: *"Regulation usually sets rigid parameters that do not apply well to the wide range of conditions encountered."* (Isenhart *et al*., op cit.).

In summary, fixed-width buffers are relatively easy to enforce, provide for regulatory predictability, and cost less to administer because those applying the regulations do not need specialized skills (Johnson and Ryba, 1992). Fixed-width buffers, however, do not account for site-specific conditions; the riparian corridor may not be adequately protected in some areas and, in others, the buffer might unnecessarily restrict development (Fisher and Fischenich, 2000, Todd, 2000, *in* Metro, 2002). In contrast, variable-width buffers account for site-specific conditions, provide a greater level of protection to important resources while reducing the impact on private property when wider buffers are unnecessary (Johnson and Ryba, 1992; May, 2000). The approach of using voluntary systems (NRCS, Iowa State) includes economic considerations as well as scientifically justified techniques, and is much more likely to gain acceptance and implementation than regulatory requirements that put farmers out of business.

3.5 Proper Experimental Design

Only a few studies have approached the issue of buffer widths experimentally, in terms of analysis of multiple buffer widths under similar conditions of vegetation, slope, and adjacent land use. These have been cited herein. Much of the ecological literature observes existing buffers and describes its function or compares it to the absence of a buffer. For example, Whitworth and Martin (1990), in assessing ecological benefits of filter strips, utilized sites with 15- to 66-foot-wide established buffers. Buffer widths in this study, as in most, were not varied as part of the experimental design, and there is no indication of what results would have been obtained with larger or smaller buffers. Fennessy and Cronk (1997) *In* Wenger, 1999) note that "*one problem in assessing minimum widths necessary to protect adjacent surface water is that many studies that make recommendations regarding the minimum width necessary have arrived at the figure as a byproduct of sampling design rather than deriving it experimentally.*" (p. 14)

Three studies reviewed for this report did approach this issue experimentally, and on agricultural lands (Dillaha *et al*., 1989; Mendez *et al*., 1999; Ghaffarzadeh *et al*., 1992). These experimental studies with variable and controlled widths provide experimental descriptions of the effectiveness of buffers by size. Dillaha (*op. cit.*) established vegetated grass filter strips (VFS) of 9.1 and 4.6 m and evaluated differences in the rate of sediment and nutrient reduction from adjacent cropland. Results for sediment reduction are shown on Figure 3.6. For a gradient of 11 percent, this study showed nearly 100 percent effectiveness for 9.1-m-wide buffers for sediment reduction (measured as total suspended solids), and between 82 and 90 percent for 4.6-m buffers. As expected, increasing gradient reduced effectiveness; a 9.1-m buffer on a 16 percent slope had an average effectiveness of 70 percent, versus 53 percent for a 4.6 m buffer. Buffer effectiveness at a gradient of 5 percent was similar to that at 11 percent: over 90 percent effectiveness was observed for 9.1 m and approximately 80 percent for 4.6 m.

Mendez (*op.cit*.) evaluated 4.3-and 8.5-m buffers as treatments for row crops, in comparison to a zero width control. Like Dillaha (*op. cit*.), Mendez evaluated buffer effectiveness in reducing sediment and nutrients from tilled cornfields. In addition, he monitored effectiveness of buffers in reducing runoff volume. Results for sediment (measured as total suspended solids) indicated that while the 8.5 and 4.3 m buffers significantly reduced sediment concentrations from the no buffer condition, there were no significant differences between the 8.5-m and 4.3-m buffer treatments (i.e., the narrow buffer is as effective as one twice as wide). Similarly, runoff volume was statistically lower with both narrow and wide buffers compared to no buffer, but there was no significant difference between the two treatments (8.5 and 4.3 m). Again, a narrow buffer was as effective as a wide buffer. Finally, Mendez showed the same results for nitrate: 8.5-m buffers significantly reduced nitrate concentrations relative to the zero meter control, but not significantly greater than the 4.3-meter buffer.

Ghaffarzadeh (*op. cit.*) found that the first 3 m of a vegetated filter strip filtered 70 percent of the runoff sediment, and approximately 90 percent in 9 meters. This study was conducted at distances of 0, 3, 6, 9, 12, and 18 meters downslope of bare, plowed surfaces.

The above experiments demonstrate the need for scientifically controlled experiments to reach valid conclusions about the effective width needed to achieve specific functioning conditions. They highlight the weakness of simply making comparisons among existing buffers that do not have experimental controls. Comparing buffers on generally steeper, forested uplands to generally lower gradient agricultural lands with different vegetation types is not appropriate in many cases and thus is not consistent with intent of legislation and regulation calling for Best Available Science.

3.6 Future Research Needs – Inadequacy of Data

The width of a specific buffer on agricultural land is highly site-specific. Lowrance (*op.cit*.) and his colleagues write: *"Buffer widths have for the most part been set and constrained by federal cost-share programs with minimal scientific evidence. We need field studies that test various widths of buffer of different plant community compositions for their efficacy in trapping surface runoff, reducing non-point source pollutants and subsurface waters and enhancing the aquatic ecosystem"* (p. 41).

In his review of Riparian Vegetation Effectiveness, Castelle (2000) concluded his review of the literature on buffer width effectiveness:

> "*Generally, there are two types of research needs. The first entails re-visiting some of the data generated by past studies that examined only one buffer size, but did not study the effects of increasing or decreasing the size of the buffer*". (p. 20). *Unfortunately, information from such studies may be construed by resource agencies and land managers as minimum guidelines. For example, if a study stated that a 30 m buffer adequately protected streams, it might be inferred that smaller buffers were studied, and that 30 m buffers should be a minimum standard width. However, if that study were re-visited using buffers of 5, 10, 15, and 20 m, it might be determined that somewhat smaller buffers may be as or nearly as effective, particularly for specific riparian functions (e.g., Figure 3.1 Chemical Removal Graph). As an alternative to studying varying buffer widths, other buffer zone management practices should be investigated. For example, stand composition could be manipulated to favor tree species which provide exposed roots (for sediment trapping), high transpiration rates (for nutrient uptake), and broad canopies (for shade production)."* (p. 20)

Castelle further remarks:

> *"The second type of needed research should focus on the interactions between vegetative and non-vegetative factors. Depending on site specifics and the nature and degree of potential impacts, it might be determined that abiotic factors are more important than vegetation in determining buffer effectiveness. These various factors can be isolated and studied in laboratory or other controlled settings, but in nature all biotic and abiotic factors work together, and isolating individual parameters provides insight into only artificial environments. In both types of research, the focus should be on the physical, chemical, and biological mechanisms, which are responsible for buffer effectiveness. Understanding why a particular buffer parameter has a certain effect will allow for more effective buffer management, which in turn will result in higher levels of stream protection and optimum timber yields." (p. 20)*

Reflecting on the larger scale of the watershed or ecosystem, what defines a conservation buffer is dependent on the intensity of adjacent land uses. Pastoral systems can serve as a buffer to row crops and agriculture itself can serve as a buffer to more intensive development of suburban and urban growth (Lowrance *et al*., p. 42). Elaborating further, they state:

> "*The optimal arrangement of conservation buffers intended to meet multiple objectives is seldom a uniformly wide green strip along a stream. Actually, buffers placed along large rivers provide habitat, bank stability and flood control function, but may have relatively less impact on water quality" " Even in headwaters, optimal arrangement calls for a variety of buffer sizes and types at different landscape locations. Very dense narrow buffers may be the most cost-effective way to reduce sediment delivery at critical points in a field or riparian area. Large blocky buffers may be needed elsewhere to provide optimal wildlife habitat and groundwater clean up" "The field--, farm-- and watershed-- scale research needed to define how to make these practices work in concert with one another has just begun."*

TABLE 3.1
COMPARISON OF SELECTED PURPOSES AND CRITERIA FROM THE USDA-NRCS NATIONAL HANDBOOK OF CONSERVATION PRACTICES FOR THE TEN CORE$_4$ BUFFER TYPES AND SOME RELATED PRACTICES

Practice	NRCS Code	Erosion Control Purposes				Other Purposes					Criteria (minimum or maximum)					
		Reduce Sheet and Rill Erosion	Reduce Concen-trated Flow Erosion	Reduce Wind Erosion	Reduce Sediment Delivery	Increase Wildlife Habitat	Reduce Contaminant Transport	Increase Carbon Storage	Produce Harvest	Protect Crops	Field Slope	Along-strip Gradient	Strip Width (SW)	Strip Spacing	Field Length	Stem Density
CORE$_4$ Buffer Types																
Riparian Forest Buffer	391[l]		+		+	+	+	+	+			along stream	>30 m			
Field Boarder	386		+	+	+	+	+					field edge	>6 m			
Filter Strip	393[l]				+	+	+				1 to 10%	<0.5%	>6 m		<50*SW	1500/m^2
Grassed Waterway	412[l]		+		+		+					along gradient		concentrated flow areas		n-VR curve, permissible velocity
Alley Cropping	311	+			+	+	+	+	+	+		contour	>6 m	species light requirements		
Contour Buffer Strip	332[l]	+			+		+				2 to 8%	<2%	>5 m (grass) >9 m (legume)	½ RUSLE Crit. Slope Length (CSL)	RUSLE CSL	540/m^2 (grass) 320/m^2 (legume)
Vegetative Barrier	601	+	+		+							<1%	>1 m	1.3 to 2.0 m vertical int.		depends on stem diameter
Shelter Belt	380[l]			+	+	+		+		+		across prevailing wind direction		12 H, +		
Crosswind Trap Strip	589C			+	+	+	+			+			5 to 8 m	upwind of protected area		
Herbaceous Wind Barrier	422A[l]			+	+	+				+			1 m	<10 H, +		at least 2 rows, 0.5 m tall (H)
Related Practices With Buffering Attributes																
Constructed Wetland	656				+		+									
Channel Vegetation	322	+	+		+		+					Channel banks				
Terrace	600	+	+		+		+					Across slope		>27 m		
Water and Sediment Cont. Basin	638		+		+		+					Across flow areas				
Grade Stabilization Structure	410		+		+		+					Field edge, side inlet				

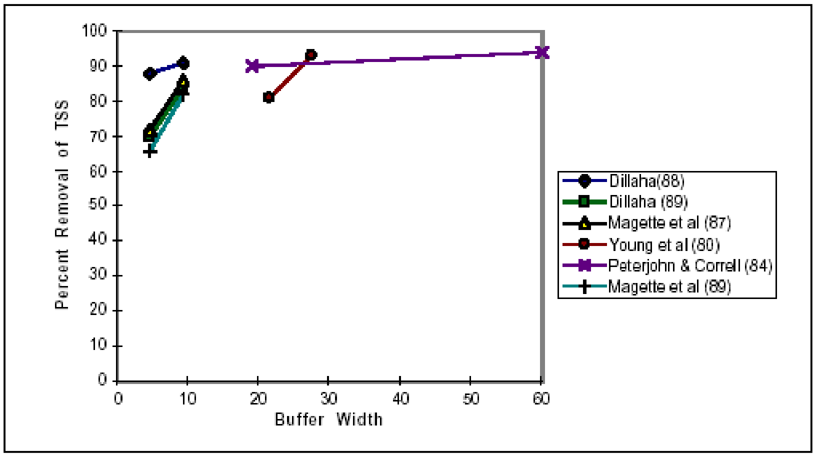

Figure 3.1
Removal of Total Suspended Solids by Buffers of Different Widths (from Wenger, 1999)
X-axis in Meters

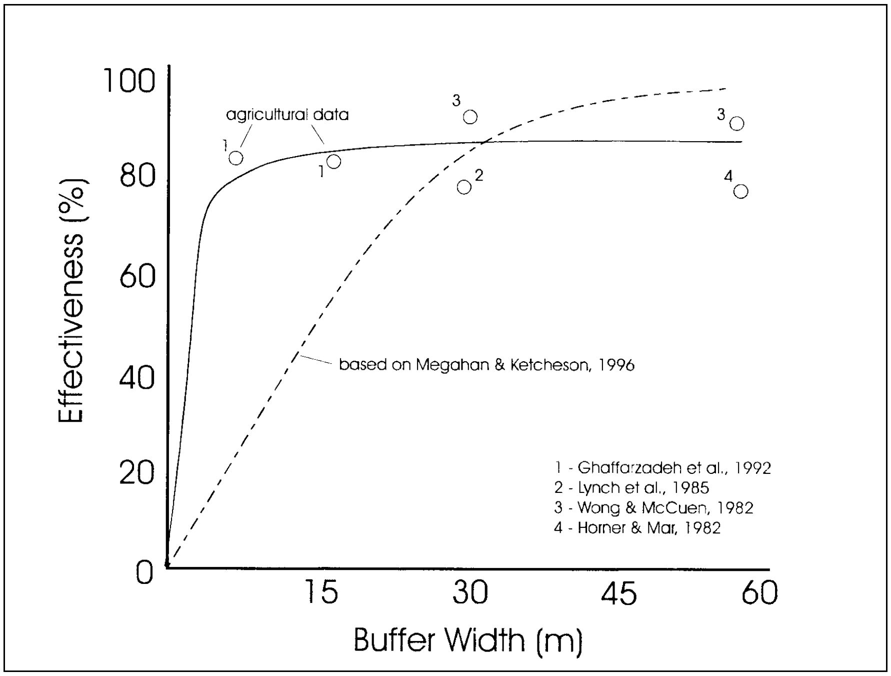

Figure 3.2
Effectiveness of Vegetation for Sediment Removal
(from Castelle and Johnson 1999).

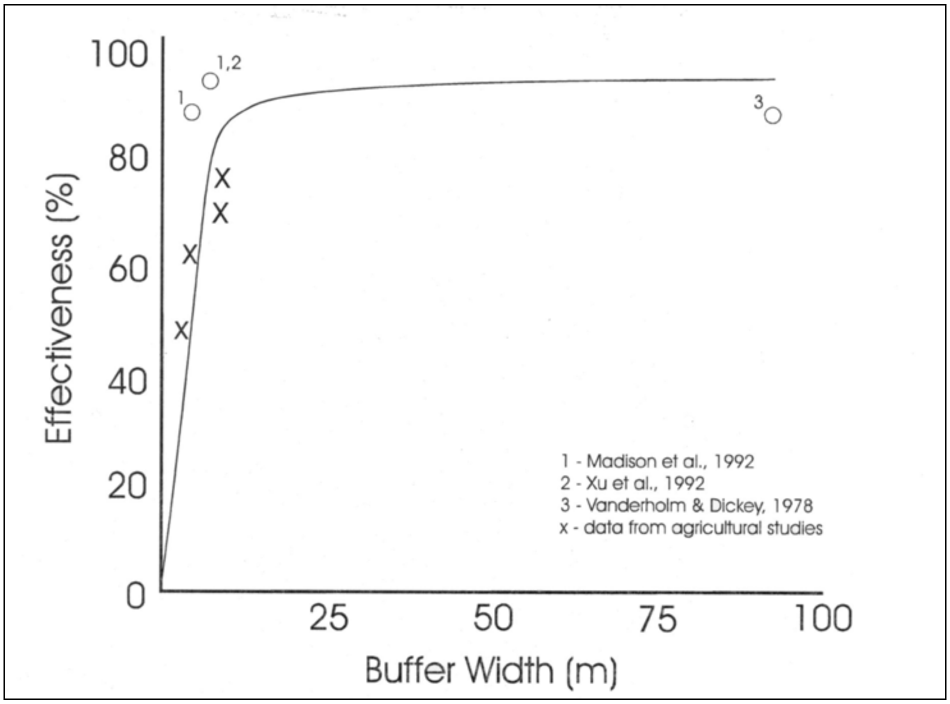

Figure 3.3
Effectiveness of Vegetation: Chemical Removal
(from Castelle and Johnson, 1992).

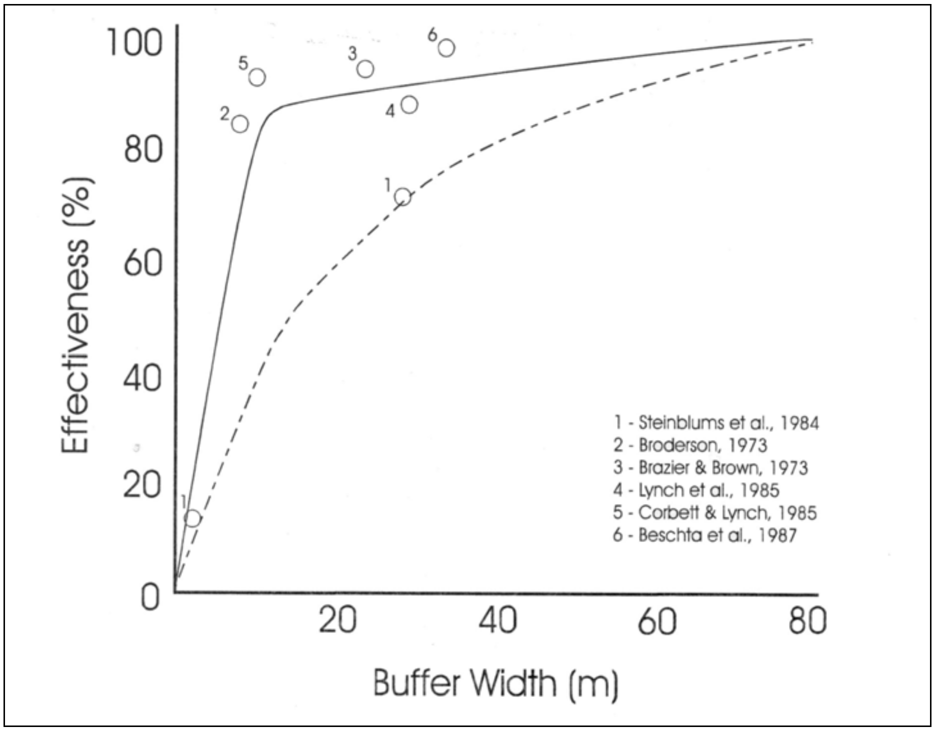

Figure 3.4
Effectiveness of Vegetation: Shade Production
(from Castelle and Johnson, 1992).

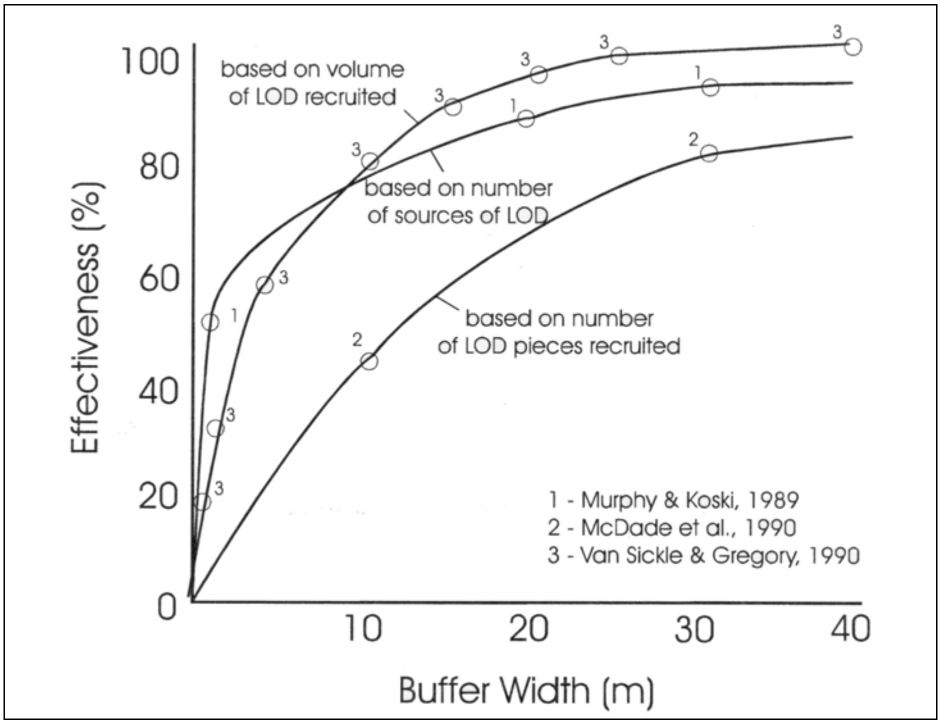

Figure 3.5
Effectiveness of Vegetation: LOD Production
(from Castelle and Johnson, 1992).

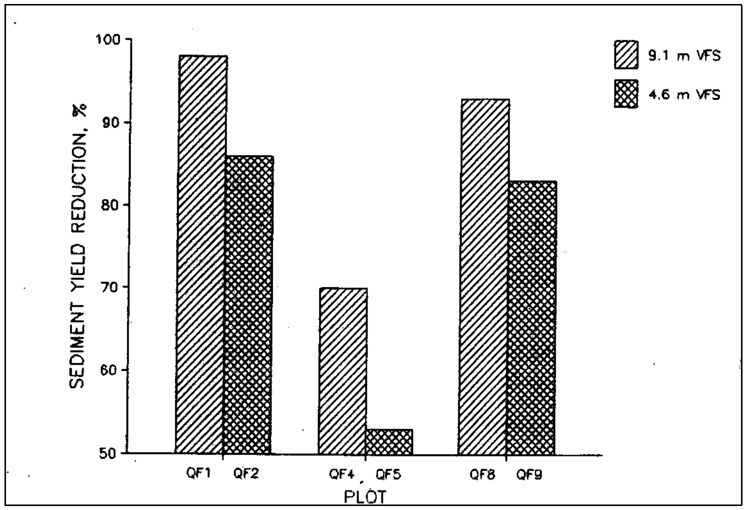

Figure 3.6
Percent Reduction in Sediment Yield from Vegetated Filter Strips
Gradients: QF1/QF2: 11%; QF4/QF5: 16%, QF8/QF9: 5%
(from Dillaha et al., 1989).

Section 4 – The Economic Significance of the Agricultural Industry and Estimated Economic Impacts from Buffer Zones

4.1 Introduction

Washington State's agricultural industry plays a meaningful role in the economy, and is often a leading economic sector for many counties located away from major urban centers. The "agricultural industry" is defined here as being composed of three key economic sectors: direct farm production, agricultural services, and the food processing industry.

This report section focuses on the economic impact of the agricultural industry and how riparian buffer zones could affect industry values. Economic impact, or significance, is described in terms of direct production value, agricultural land and local taxation values, and the direct and secondary economic affects on local and state income. These types of values and economic measures can be applied to an assessment of economic impacts directly related to buffer zones, and examples of such are estimated. The industry values and economic impacts are presented at the state level, and they are developed for selected counties for illustration purposes. The selected counties reviewed here are representative of east- and west-side counties that host large agricultural economic bases and would likely be affected by buffer zone management regimes.

The following information provides an overview of the agricultural industry's economic base for the State, the industry's economic influence within selected counties, and general or "index" value impacts that would result from buffer zones. Related issues also are discussed, including factors for consideration in water use reallocation and more vigorous economic frameworks from which to judge the economic effectiveness and trade-offs inherent to developing buffer zones.

4.2 Farm Production Values

Agricultural production values can be expressed in several ways, but one of the more common measures is farm-gate value, the gross revenues received by farm operators for their products. These values represent the total dollars that are received by farm producers, most of which are then spent locally, regional, or nationally to cover production expenses. A small percentage of farm-gate value usually "stays in the hands" of owners and managers, but the bulk of the value is transferred to other sectors of the economy to cover the variable and fixed costs of farm operations. As such, farm-gate value can be viewed as the total value of input costs to the primary farm production sector, plus the value of farm management, labor, and investment returns.

At the overall state level, the farm-gate value for agriculture amounts to about $5.4 billion in year 2000 dollars (National Agricultural Statistic Service, 2002). About $1.7 billion are derived from field crops, about $1.2 billion from fruits and nuts, and about $1.5 billion from livestock and direct products. During the past decade, the year 1995 represents the peak production value year, with about $5.8 billion in gross farm-gate revenues. Since then, many commodity prices have fallen, particularly in the tree fruit industry.

For selected counties, Tables 4.1 and 4.2 summarize the farm-gate values received by farm operators for their leading crop and livestock products, based on a 1998 through 2000 annual average value range.

TABLE 4.1
FARM-GATE VALUES

Farm-Gate Value For Leading Value Crops, 1998 to 2000					
County	**Crop**	**Production Values, by Year (Year 2000 Dollars)**			**Annual Average Production Value 1998-2000 (In Year 2000 Dollars) ($/Acre for Key Crops in Parentheses)**
		1998	**1999**	**2000**	
Benton	Apples	84,285,796	93,518,335	82,475,828	86,760,000 (4,500)
	Cherries	23,763,423	21,130,520	27,704,002	24,199,000 (8,600)
	Grapes	44,503,785	45,342,446	46,124,331	45,324,000 (2,900)
	Potatoes	89,312,812	96,935,700	91,825,500	92,691,000 (3,000)
	Hay	9,317,351	10,102,800	13,088,000	10,836,000
Kittitas	Apples	8,504.059	9,435,581	8,321,442	8,754,000
	Pear	1,514.171	1,679,069	1,435,818	1,543,000
	Hay, total for crop	29,666,317	31,901,928	33,502,000	31,690,000 (600)
	Potatoes	1,103,855	1,009,476	1,096,500	1,070,000 (1,800)
	Wheat	676,790	n/a	8,321,442	4,499,000
	Oats	118,093	137,088	132,000	129,000
Skagit	Apples	1,633,109	1,811,997	1,598,039	1,681,000
	Corn	11,025,509	9,424,188	8,464,500	9,638,000
	Hay, all	3,071,495	2,489,004	3,188,600	2,916,000 (280)
	Potatoes	13,151,786	12,750,000	14,088,750	13,330,000 (1,700)
	Green peas	n/a	3,836,009	2,193,740	3,015,000
	Wheat, all	826,358	882,259	1,131,300	900,000
Yakima	Apples	344,297,757	382,011,614	336,904,243	354,405,000 (4,400)
	Cherries	45,245,735	40,232,668	52,748,626	46,076,000 (7,100)
	Grapes	43,386,232	44,203,833	44,966,083	44,185,000 (2,700)
	Pears	46,614,506	51,690,966	44,202,386	47,503,000
	Hay, all	20,997,486	19,852,872	22,520,000	21,123,000

Note:
Sources: See Economics Appendix C.

The leading crop values for the selected counties are displayed in Table 4.1. To a large extent, the direct production values for Benton and Yakima Counties illustrate the large contribution agriculture can make to local and regional economies. The combined fruit and crop production amounts to about $260 million in Benton County, and about $513 million in Yakima County.

And within Kittitas and Skagit Counties, fruit and crop production values comprise about $43 million and $29 million, respectively.

TABLE 4.2
FARM-GATE VALUES

Farm-Gate Values for Animal Production and Products, 1998 to 2000					
County	**Commodity**	**Total Farm Gate Values by Year (2000 Dollars)**			**Average Farm Gate Value (Dollars)**
		1998	**1999**	**2000**	
Benton					
	Milk Production	8,097,563	7,921,844	6,607,440	7,542,000
	Cattle & Calves	8,079,766	6,882,698	8,913,090	1,956,000
	Hogs & Pigs	36,241	35,118	49,840	40,4000
	Sheep	91,214	77,306	83,545	84,022
Kittitas					
	Milk Production	1,913,841	1,873,179	1,562,022	1,783,000
	Cattle & Calves	20,776,092	17,697,880	22,919,233	20,464,000
	Hogs & Pigs	63,167	57,695	82,357	68,000
	Sheep	176,095	140,789	152,152	156,000
Skagit					
	Milk Production	72,520,769	69,535,810	59,409000	67,156,000
	Cattle & Calves	21,930,232	18,681,854	24,192,250	21,601,000
	Hogs & Pigs	71,635	69,311	69,391	80,000
	Sheep	26,835	22,782	24,621	25,000
Yakima					
	Milk Production	181,832,563	174,352,096	148,357,314	168,381,000
	Cattle & Calves	130,949,365	90,212,420	133,207,488	118,123,000
	Hogs & Pigs	189,417	173,971	247,172	204,000
	Sheep	792,458	633,549	690,908	706,000

Note:
Source: See Economics Appendix C.

Milk production and livestock are significant local industries within counties like Skagit and Yakima, holding high production values (Table 4.2). The average annual milk and livestock production values amount to about $89 million in Skagit County, and about $287 million in Yakima County. For Benton and Kittitas Counties, the annual value of milk and livestock production is about $16 million and $22 million, respectively.

These farm-gate values transfer into expenditures for agricultural services and goods, equipment, supplies, labor, and other production inputs obtained from local, state, and out-of-state areas.

4.3 Agricultural Land Values and Taxation Rates

Table 4.3 displays estimated agricultural land value ranges (market values) for the selected state counties. The land values are important to local areas both as retained, long-term capital value for farm owners and as the base value for local taxation to support infrastructure projects and services (schools, roads, hospital districts, fire districts, other). Also, these land values represent values for the maintenance of agricultural production, not values associated with the transformation of agricultural lands to non-agricultural uses.

As presented in Table 4.3, the estimated land values for agriculture in Skagit County range from about $2,800 to $4,000 per acre. Higher values can be obtained for certain specialty crops, like blue berries, depending on the condition of the field. A similar range exists for Kittitas County, with values at about $2,000 to $3,000 per acre for most farm ground (including some value for site buildings as estimated by the Census of Agriculture).

Higher land-value ranges occur for Benton and Yakima Counties due to the higher percentage of specialty crops—wine grapes, cherries, and certain apple varieties—grown within the region. Land values here are about $3,500 per acre for high quality row-crop ground, and as much as $7,000 per acre (or more) for specialty crop ground. These land values include the value of water rights (or water delivery) and irrigation distribution systems (on-site irrigation systems).

Taxation rates for agricultural areas vary depending on what is included within the county tax base (exclusive of other consolidated land taxes), but a mid-range value would be about $10 to $14 per $1,000 of assessed land value (Pacific Northwest Project, 1994, 2001). If assessed land values (exclusive of buildings and other improvements) are assumed to reflect the lower range of the land market values (assessed values are typically lower than average market values), then the local tax benefits for the lands identified in Table 4.3 would amount to about $42 per acre, or $6.4 million for Benton County; about $24 per acre, or $1.8 million for Kittitas County; about $34/acre, or $3.1 million for Skagit County; and about $30 per acre, and $8.3 million for Yakima County (at $12 per $1,000 value tax rate).

Actual tax revenues obtained from agricultural lands, for each county, will depend on specific land assessments including improved property, and tax rates, but the above estimates serve as a useful and realistic value for consideration across statewide agricultural lands.

Also, it is important to note that agricultural land (market) values are significantly different than land values for undeveloped, idle ground. The difference is usually at least a factor of 5 to 10 or more. Consequently, for many counties, the developed agricultural lands are a major source of county revenues to support local infrastructure and services.

TABLE 4.3
ESTIMATED LAND (MARKET) VALUES FOR SELECTED COUNTIES

County	Total Farmland (Acres)	Estimated Land Values ($/Acre)	Estimated Total Values ($ Millions)	Estimated Average Value ($ Millions)
Benton	153,000*	$3,500-$7,000**	$535-$1,071	$803
Kittitas	75,600*	$2,000-3,000	$151-227	$189
Skagit	93,000	$2,800-4,000+	$260-372	$316
Yakima	277,000*	$2,000-$7,000	$554-$1,939	$1,247

Notes:
Sources: Census of Agriculture, Washington, 1997; Personal communications with Polygon Management (farming and land developers), Mount Vernon, Washington, and Northwest Farm Management/Clark Jennings and Associates, Pasco, Washington (commercial agricultural land managers and brokers), July 2002; and review of active REALTOR MLS listings for Skagit County and Kittitas County (internet sites), July 2002.
* Irrigated acreage only.
** Irrigated agriculture for production agriculture only.

To the extent that buffer zones would be adopted within these selected counties, individual landowners would incur reduced land and farm production values, and the local economic benefits of production agriculture would diminish. Adverse economic impacts would include both secondary economic impacts and reduction in local taxation benefits.

4.4 Measuring Economic Impacts within State and Local Economies

The regional economic impacts of the agriculture industry—including impacts from direct agricultural production, agricultural services, and food processing—can best be described in terms of direct income (or earnings) and the secondary or "indirect" income it creates in other sectors of the economy. This direct and indirect relationship is often referred to as the multiplier effect, the secondary economic impact generated by "basic" economic sector activity. This dependence and multiplier effect exists within state, regional, and local economies.

Economists and regional planners often refer to specific sectors of local or regional economies as either being basic (export-based) or non-basic (service). In particular, economists are interested in how changes to the basic economic sectors affect secondary and induced economic activity within an area. Some economic activities exert multiplier effects to relatively confined local areas (labor services), while others create economic activity throughout a state or larger area (equipment purchases and durable manufactured goods).

While there are several different types of multipliers to gage the magnitude of economic activity within a defined area, the emphasis on income multipliers reflects a conservative perspective. Income does not depict the value of goods and services traded by a specific economic sector; it only constitutes the actual net income produced by a set of economic transactions that actually stays within the defined area. For example, the agricultural sector may purchase farm equipment within a local county, but most of the income value of the purchase flows to the county of origin where the equipment was manufactured. Economists refer to this transfer of value outside the county of purchase as “leakage.” Consequently, income multipliers only measure an economic sector’s real income generation within a fixed area (defined economy) and tend to be “lower values” when compared to other types of measures, such as the value of production for affected goods and services. But for many economists and decision makers, the “bottom line” question surrounding an economic activity is: how much real income did this activity bring into my county or state?

There are several tools or methodologies that can be employed to measure the multiplier effect of specific types of economic activity (see Schaffer, 1999, and Bendavid-Val, 1991, for an overview of impact models, methodology, and applications). These include economic base analyses (location quotient or minimum requirements methods), and input-output analyses that review the cumulative economic transactions among multiple economic sectors. These methods each have advantages and disadvantages. Economic base methods do not require extensive data, but are limited in accuracy; their application must take into account distortions in geographical scope and interaction with other types of basic economic activities within a specified economy. In contrast, input-output (I/O) analyses (models) can require an extensive amount of data and adjustment, but they yield far more descriptive and usually accurate information about specific economic sector impacts.

For review purposes here, estimates of direct and indirect economic impact within states and counties based on contributions to income are measured using the IMPLAN modeling system. IMPLAN is an I/O model that has been used in numerous economic impact studies and is maintained by a technical consulting group (Minnesota IMPLAN Group). The basic model consists of regional and national data and I/O algorithms for impact analysis. The IMPLAN model is based on national average economic relationships between economic sectors, buying and selling of goods and services with state and regional (county) level data adjusted or recalibrated to better match regional transactions (from regional data obtained from the Bureau of Economic Analysis). As such, IMPLAN is an I/O model that allows for an assessment of regional economic conditions using non-survey data, providing for an acceptable range of accuracy for the purposes needed herein.

Based on consultations with IMPLAN technical support staff, IMPLAN is used for state and county-level analyses to estimate direct and indirect economic impacts for the agricultural industry, with modeling adjustments made to avoid double-counting errors among the agricultural production, agricultural services, and food processing sectors. The I/O model uses 1999 regional data for calculating sector relationships. The income values depict 2000 data and expressed in year 2000 dollars. A state-level analysis is used to illustrate the "linkages" among the major economic sectors, for example, the buying and selling of goods and services by the agricultural production and food processing sectors to several other sectors of the economy. By identifying these linkages, the flow of economic activity created by the agricultural industry can be revealed.

Estimates of direct and secondary income effects from agriculture and irrigated agriculture are displayed in Table 4.4. These estimates are based on 1999 I/O model data (recent version of IMPLAN model with 1999 data sets), with the resulting direct and indirect relationships carried over to the most recently available Bureau of Economic Analysis state income data sets (2000 data). The I/O model estimates for indirect income generated by the agricultural industry sectors are founded on conservative modeling techniques to avoid double-counting and other errors that could over-estimate the direct and indirect based on consultations with IMPLAN Group technical staff and a review of Rodolfo *et al*. (1996).

TABLE 4.4
AGRICULTURAL INDUSTRY DIRECT AND SECONDARY ECONOMIC IMPACTS*

Washington State and Selected Counties	Agricultural Industry Direct Income ($ Millions)			Total Direct & Indirect Agricultural Industry	Ag. Industry % of Total Industry Income
	Agriculture Production (Direct)	Agricultural Services (Direct)	Food Processing (Direct)		
Benton	$97	$22	$80	$307	17%
Skagit	$77	$15	$32	$228	13%
Yakima	$369	$57	$124	$1,050	41%
Washington State	$1,379	$890	$1,461	$7,768	7%

Notes:
Sources: U.S. Dept of Commerce, Bureau of Economic Analysis Data Series, Regional Economic Information System (REIS) 2000 data series, Minnesota IMPLAN Group 1999 model data bases, and modeling analyses prepared by Pacific Northwest Project, June-July 2002.
*Income defined by Bureau of Economic Analysis as net earnings by each economic sector.

In Table 4.4, Washington State and selected county estimates are reviewed for direct income (in year 2000 dollars) derived from the agricultural industry. The industry generates about $3.7

billion in direct income, representing about 2.8 percent of the state's $136 billion industry-related income, not including government and government services. Compared to other state industry-group sectors, the agricultural industry ranks fifth in producing direct income. The four leading sectors are health services, the combined finances insurance and real estate business, manufacturing of transportation equipment, and engineering and management services (Bureau of Economic Analysis, 2000).

Also in Table 4.4, state and selected counties were directly modeled with IMPLAN, producing an overall agricultural industry multiplier for the state of about 2.3 (multiplier is for aggregated agricultural production, agricultural services, and food processing sectors). That is, for every dollar of income directly produced by the agricultural industry, an additional 1.3 dollars of income are indirectly generated within the state economy. This estimate is slightly higher than previous IMPLAN modeling estimates using 1994 data, which suggested a state multiplier of about 2.0 (Pacific Northwest Project, 1998). The larger 2000 multiplier would tend to indicate that the percentage of higher-value and value added crops (more food processing) in the state has increased slightly since the mid-1990s.

The model analyses for the selected counties suggest multipliers ranging from about 1.5 to 1.9, which is consistent with other analyses for county-level income multipliers dealing with county and regional level data (IRZ Consulting and Pacific Northwest Project, 1998; Pacific Northwest Project, 1996, 1998; Northwest Economic Associates, 1994). This produces a range of about 1.7 to 2.0. Based on these data estimates, a "general" county multiplier of about 1.8 would be acceptable for broad-based observations across the state, representing a conservative estimate of county impacts relative to the economic sector linkages involved. The extent of the economic sector links (total generation of income) is less within counties than at the state level; thus, the income multiplier for counties is less than at the state level.

The indirect income effect represents the flow of dollars through the economy that create secondary income in economic sectors indirectly supported by the agriculture industry. The total amount of annual (2000) state income generated by the agricultural industry—agricultural production, agricultural services, and food processing—is about $7.8 billion; the indirect portion being about $4 billion. At the overall state level, the agricultural industry generates about 7 percent of the total household income, not including the government and government services sectors (direct and indirect income).

At the county or regional level, the agricultural industry's impact can be far more pronounced. For example, in selected counties that could be directly affected by buffer zones, the income contribution ranges from about 13 percent to over 40 percent, not including the government and governmental services sectors.

Relative to the issue of buffer zone impacts at the county level, the above economic analyses indicate that buffers would be affecting economic sectors that are major contributors to income and economic activity within affected counties. The important questions become: (1) to what degree would buffer zones impact income generation, and (2) can such zones be managed to reduce economic impacts?

4.5 Sector Linkages within the Economy – The Flow of Economic Transactions

One further point should be made in considering the direct and indirect economic impacts exerted by the agricultural industry. The industry affects almost all economic sectors of the state economy. This is observable through the I/O modeling exercise, where the links between economic sectors are identified and the purchases (or sales) estimated (see Table 4.5).

The links represent the buying (input) and selling (output) conducted among the different economic sectors as they develop products and provide services within the overall economy. This activity is often referred to as the "flow" of economic transactions within an economy.

Table 4.5 displays the economic links associated with the agricultural industry for the State of Washington (1999 data). Estimates of inter-sector buying and selling are quantified based on the IMPLAN modeling assumptions (Minnesota IMPLAN Group, 1999). The economic links indicate that Washington's irrigated agriculture industry annually (1999) buys about 60 to 70 percent of the value of purchases made by the direct agricultural production in Washington. Food processing sectors buy from other economic sectors within the state (about 30 to 40 percent out-of-state); and the agricultural services sector buys about 30 percent of its value of purchases from other in-state economic sectors.

At the county level, similar ratios exist for local versus non-local purchase values. For the selected counties, the direct agricultural production and food processing sectors buy about 60 percent of their value of purchases from other local economic sectors, with the agricultural services sector buying about 20 to 30 percent of its value of purchases from other local sectors (Minnesota IMPLAN Group, 1999 data sets).

TABLE 4.5
ECONOMIC SECTOR LINKAGES TO THE AGRICULTURE SECTOR
(IMPLAN MODEL AND 1999 DATA ESTIMATES)

Economic Sectors	Agricultural Production Buying From State Economic Sectors	Agricultural Services Buying From State Economic Sectors	Food Processors Buying From State Economic Sectors
	Total Purchase in 1999 ($ Millions)	Total Purchase in 1999 ($ Millions)	Total Purchase in 1999 ($ Millions)
Agricultural Production	458.9	73.3	1,343.7
Ag Services	268.0	2.7	3.6
Construction	87.4	13.7	67.6
Food processing	131.6	0.8	451.5
Wood products	13.3	0.0	1.4
Chemicals and allied	84.2	20.8	44.7
Petroleum products	72.2	6.0	25.1
Industrial machinery	9.6	0.5	5.5
Electrical equipment	9.1	0.9	1.0
Transportation equipment	7.0	2.1	7.1
Railroads & Related Services	21.4	0.8	36.6
Motor Freight Transport & Warehousing	77.7	8.7	171.6
Water Transportation	8.4	0.4	25.4
Transportation Services	2.9	0.4	3.9
Communications	14.0	5.1	29.7
Utilities	52.3	0.5	76.1
Wholesale Trade	298.8	36.8	674.3
Retail Trade	0.5	1.7	43.8
Financial Institutions	49.1	13.0	115.7
Real estate	247.2	8.2	34.8
Hotels and Lodging Places	2.3	1.9	36.0
Business services	11.4	13.2	328.3
Automotive services	23.6	15.1	39.7
Repair services	17.3	1.5	20.5
Health services	12.6	0.0	0.0
State & Local Non-Educational Government	25.7	2.1	47.4
Other Sectors	21.9	41.1	163.4
TOTAL	**2,028**	**271**	**3,799**

4.6 Direct Economic Impacts from Buffer Zones – What is at Risk?

While the economic impacts of buffer zones are very site-specific in nature, depending on the type and extent of land and farm operations being affected, there are methods that can be used to estimate indicator or "index values" for such impacts. Because the index values represent generalized estimates of broad-based compiled data sets and assumptions, they should not be considered as "precise impact values." In many circumstances they would underestimate or overestimate economic impacts because of their comprehensive basis for compilation.

Nevertheless, they can be used to assess an approximate magnitude of impact and would be appropriate for general resource planning and decision-making purposes, where broad-based economic impacts are being considered.

The methodology used to estimate the index values for the selected counties is developed in Table 4.6. In Table 4.6, crop, milk production, land, and local income values are estimated on a value per acre basis for each county, given the available production estimates and data sources. Using this methodology and data sources, crop production values per acre range from about $600 to $4,500, dairy production values per acre range from about $4,050 to $5,400, county income values per acre range from less than $1,000 to about $2,400; and land values per acre range from about $2,500 to $5,250. Values are weighted averages.

TABLE 4.6
ESTIMATED INDEX VALUES FOR AVERAGE AGRICULTURAL PRODUCTION AND LAND VALUES

Counties	Affected Crop Production Value/Acre	Average Dairy Production Value/Acre*	Average County Income Value/Acre	Average Land Value/Acre
Benton	$4,500	------	$1,900**	$5,250
Kittitas	$600	------	< $1,000***	$2,500
Skagit	$1,700	$4,050	$2,400***	$3,400
Yakima	$4,000	$5,400	$1,900**	$4,500

Notes:
* Based on average dairy farm size of 400 acres east-side and 200 acres west-side, 2000 average value milk production estimates above, and Census of Agriculture estimates for total dairy farms per county; information from Soil Search Consultants, Kennewick, Washington, July 2002; and Washington State Dairy Federation staff (estimated average dairy sizes for Washington state); and milk production values from above tables and sources cited therein. Value is highly sensitive to assumptions about number of farms and average size.
** Based on irrigated crop lands for Benton County and Eastern Oregon, USACE 2000, Pacific Northwest Project 2001, and IRZ Consulting and Pacific Northwest Project 1998.
*** Based on above direct and secondary income estimates for Skagit and Kittitas Counties and total estimated farm acreage.

The values derived in Table 4.7 are converted to potential value losses related to buffer zones, where the zones are defined as value per mile of 75-foot buffers, for both sides of the affected stream. The general assumption for value loss is based on loss of economic activity tied directly to affected land acreage. For illustration purposes here, it is assumed that all acreages included within buffer zones would have a uniform or linear impact on the various measures of local economic value, such as crop production, milk production, and county income. On an empirical basis, this may or may not be the case, depending on the extent that economic activity is allowed within some portion of the buffer zone, the Table 4.7 index values would overstate the levels of impacts. Inversely, to the extent that a buffer zone caused a farm operation to be no longer economically viable, forcing it to go out of business, the index value would underestimate the impact magnitude.

TABLE 4.7
ESTIMATED INDEX VALUES FOR BUFFER ZONE IMPACTS

Counties	Crop Value Loss/Mile 75 ft Buffers*	Dairy Prod. Value Loss/Mile 75 ft Buffers*	Ave. County Income Loss/Mile 75 ft Buffers*	Ave. Land Value Loss/Mile 75 ft Buffers*	Ave. County Income Loss/100 acres of Buffer
Benton	$81,000	------	$34,200	$94,500	$190,000
Kittitas	$10,800	------	------	$45,000	------
Skagit	$30,600	$66,960	$43,200	$61,200	$240,000
Yakima	$72,000	$88,200	$34,200	$81,000	$190,000

Notes:
Table values based on above tables and sources cited therein.
* Assumes riparian buffer impacts on both sides of stream, approximately 18 acres per mile.

4.7 The Farm Economics of Agricultural Buffer Zones – Some Examples

One of the best ways to understand the economic impacts of buffer zones on farm owners is to review available examples where farm managers have installed buffers. The Natural Resources Conservation Service has provided a multi-state case study of several farm types and buffer programs currently in operation (USDA-National Resources Conservation Service, 1997). By reviewing this information, it is possible to identify certain trends affecting farm economics and the types of buffers being implemented.

First, large riparian buffers, about 50 feet wide, have been adopted by some landowners (without compensation) where high-value crops are involved, such as oranges and grapes, and where acreages affected are relatively large (100 acre blocks or larger). Some farmers have accepted the buffers as “a cost of doing business,” relying solely on the buffer zones to protect water quality, as opposed to employing other management tools. The high-value crops allow farm operators greater flexibility to adjust to relatively large buffer zone sites, and other direct land management actions are relegated to resolution by buffer zones. Examples are cited from Florida and California.

Examples where relatively large riparian buffers about 35 to 50 feet wide have been adopted by landowners and farmers involve large acreages (greater than 500 acres), and it has been the landowner’s choice to use buffers as a preferred management alternative to control for water quality problems. Here the affected lands do not appear to contribute significantly to farm production revenues. Landowners with large acreages are receiving acceptable compensation through the CRP program to offset costs. Examples are cited from South Carolina and New York.

In Utah, Oregon, and Idaho, some examples are offered where buffers are limited to agricultural management zones, where cover crops and animal grazing periods are controlled. Some range operations are providing minimal buffers but have fenced livestock away from critical stream habitat areas. In these examples, the application of buffer zones is limited or includes multi-purpose land management objectives that minimize the costs involved to farmers and ranchers.

What emerges from these buffer zone examples is that buffer applications have been tailored to meet the specific economic circumstances of individual farmers. Farm operators have elected to adopt buffer zones that do not measurably interfere with or negatively impact farm economic vitality. In these cases, cost and/or compensation is an important factor in buffer zone applications.

4.8 Agricultural Water Reallocation and Buffer Zones – Economic Issues

The economics of buffer zone impacts can be, and often are, related to water reallocation actions. This can occur indirectly in terms of water rights affected by irrigated land loss to the buffer zone, thus reducing the water quantity of the water right held by the land owner; and it can occur directly in an economic sense, where the question of water value trade-offs occur for fish or other non-market value resources.

The economic value of water can be expressed in terms of direct net value (National Economic Development standards used by federal water resources agencies) per acre-foot of water used for specific sectors, such as irrigation, municipal, hydroelectric power production, fisheries and wetlands restoration or enhancement, and recreational activities. Several estimates of the value of water related to these activities have been made in the west, depicting economic values derived from (1) use of market transactions (irrigation, hydroelectric power, and commercial fisheries sectors), (2) use activities that are non-market in nature (sport fisheries and recreation), and (3) option and existence values related to both non-use and non-market perceptions of value (various types of environmental resources) (for example, see summary in Pacific Northwest Project (1998).

Any review of economic value estimates for water resources brings forward several issues surrounding water use trade-offs, such as reallocating water away from irrigated agriculture to environmental resources. First, while the value of water for irrigated agriculture falls within a relatively narrow range, the water values for environmental resources can be either well below the value of irrigation, or they can appear to be much higher. This suggests that relying on preconceived assumptions about the economic benefits or costs of water transfers will likely lead to poor water reallocation decisions. The economic benefits and trade-offs must be dealt with on a local or regional basis.

Second, it should be noted that while water values for irrigation are "user values," many water values (or much of the economic value) for environmental resources are non-use values. In fact, much of the value attributed to environmental resources is a non-use, non-market value that is quantified through survey methods into monetary terms. For example, survey respondents are asked to state their "willingness-to-pay" for environmental resources that would be protected or restored to some positive condition (some very specific examples of this methodology for the Northwest region are in Pacific Northwest Project, 1994; Olsen, D. *et al*., 1991; and Olsen, D. 1993; and also refer to Loomis, 1997).

When we compare water values for irrigation to those for non-use, non-market entities, the economic nature (or actual impact) of the direct net values is quite different. For example, the direct net value for irrigation consists of material production that generates direct net economic activity and secondary/regional economic activity-both of which can be measured in terms of net production value, income, or employment. When non-use values are measured, no actual income is generated within the economy. What is being measured is an expression of willingness-to-pay, which may or may not be an accurate measurement of economic value (consumer surplus value if a market transaction could actually be provided), and may or may not be considered as contributing to measures of real income gain. There is a tangible difference between actual direct net value within a real market transaction or use circumstance, versus the pure perception of economic value. This is an issue that some resource economists believe should temper how existence values are used, and may limit their relevance when being contrasted directly to use values-particularly when the existence values exceed use value by several factors.

Third, non-use, non-market measures of existence value are seldom handled equivalently between resource comparisons. For example, while economic valuation estimates have been made to capture use and non-use values for many environmental resources, existence values are seldom, if ever, considered for activities such as the irrigation sector; there is, no doubt, some existence value that society attaches to irrigated agriculture and all of its environmental qualities, either real or imagined. This can be illustrated by the types of economic valuation studies that have been recently conducted for the Central Valley Project and the Columbia-Snake River Basin (major EIS studies conducted by the USBR and Army Corps of Engineers). Non-use existence values have been estimated for fish resources (which also retain use values), but no attempt is made to calculate non-use existence values for the irrigation sector benefits. In effect, the value estimates used to assess economic trade-offs, in these situations, are not equivalent in structure.

Consequently, the economic trade-offs involving water reallocation decisions must be weighed with great caution. While decision makers may harbor the best of intentions, the end result of incompletely reviewed decisions could lead to a real loss of economic benefits.

4.9 Assessing Economic Impacts from Buffer Zones – Three Methods

There are some standard economic "tools" that are employed to assess land and water use impacts when considering major project developments or when significant economic sector trade-offs are being contemplated: benefit-cost analysis, marginal benefit assessment, and cost-effectiveness analysis. Unlike local or regional impact analyses that concentrate on measures of income or employment (Regional Economic Development), these tools primarily focus on measures of direct net value and net social welfare trade-offs between major economic sectors (National Economic Development values).

Benefit-cost analysis could be employed to measure the direct net benefits versus costs for setting aside buffer zones for specific streams and counties. To do so, the direct net value of production per acre (cost) would be contrasted to the direct net value of fish resources, based on increased fish production leading to increased sport and commercial fishing (benefits). The cost would not be difficult to measure, and the benefits could be estimated based on assumptions affecting the increased survival rates for fish for specific stream reaches. Alternatively, the agricultural cost estimate could be used as an economic criterion to assess the required fish production increase per acre to balance the benefit-cost trade-off.

A marginal benefit assessment would scrutinize the value of incremental benefits—fish production or habitat units—based on specific actions taken. For example, a review of the litter-fall effectiveness for habitat enhancement by the Oregon Forest Industries Council (CH2M HILL, 1999) demonstrated that FEMAT effectiveness curves produced very little effectiveness per tree height distance (unit) from streams beyond a unit value (tree-height) of 0.5. In effect, the marginal value of the buffer zones' effectiveness, based on tree-height distance, declined sharply after a 0.5 unit value. Other studies suggested even more limiting marginal values of effectiveness. Under marginal benefit assessment, the production gained per incremental input unit of increase is evaluated and, at some point, diminishing gains per unit of input are deemed to be unacceptable or providing inadequate production value.

Cost-effectiveness analysis could be employed where a specific objective is sought, and different alternatives to achieve that objective are possible. The emphasis is on finding a more cost-effective solution to the problem rather than comparing different sectors' direct net value changes. For example, if the objective is to control water quality impacts from animal wastes, then the annual costs of buffers per unit of control (reduced impacts to water) can be compared to the annual costs of animal waste management measures. Cost-effectiveness analyses could be employed in a more detailed economic review of buffer zones for specific areas, such as the Skagit Valley.

All of these analysis tools offer a means to consider economic sector trade-offs and marginal benefits and costs (USDA-Economic Research Service, 1999). Still, returning to a regional economic development (RED) perspective and framework, it should be understood that direct land impacts to specific agriculture production operations may be marginal, but can remove the profitability from the operation, thus forcing producers out-of-business. Consequently, a buffer could have a relatively small land impact, but result in forcing a farming operation out-of-business, affecting the direct and secondary income stream throughout the community. Then the economic question becomes, will the buffer zones generate economic activity from other sectors, and provide income to the local area to offset the direct impact to production agriculture?

4.10 Summarizing Key Points – Agricultural Economic Base and Impacts

Some highlights and key points of the preceding technical analyses and observations are summarized below:

- Farm-gate production values exceed $100,000,000 annually in several Washington State counties. This production value is largely transferred to other sectors of the county, state, and national economies creating further economic activity.
- The agricultural industry increases land values in several rural counties, contributing millions of dollars to each county tax base—paying for infrastructure and services.
- The agricultural industry, including agricultural production, agricultural services, and food processing-is a significant economic sector within Washington State, generating almost $8 billion annually of state income. In particular, the agricultural industry is a leading economic sector in several counties located away from the major urban centers.
- The agricultural industry possesses linkages to almost all other economic sectors of the state economy—buying and selling diverse goods and services throughout the state.
- Representative “index values” can be calculated at the county level to estimate the regional impacts of 75-foot buffer zones. On a per mile basis, the costs of buffer zones (for selected counties reviewed here) could range between $11,000 to $81,000 for affected crops; $72,000 to $97,000 for affected dairy production; and $45,000 to $95,000 for affected land values. On a 100-acre impact basis, the loss of total county income (direct and secondary) could range between $190,000 to $240,000 annually.

- Water reallocation issues can be tied to buffer zone impacts. Because of the varying economic value of water within economic sectors, relying on preconceived assumptions about the economic benefits or costs of water sector transfers will likely lead to poor reallocation decisions. The economic benefits and trade-offs must be dealt with on a local or regional basis.
- In water, land, and environmental resources valuation and trade-off decisions, the use of non-market values should be approached carefully. The value ranges can vary greatly depending on the quality of measurement, some non-market values do not reflect real measures of income gain or loss for an economy, and non-market values are seldom handled equivalently among resource comparisons.
- There are elaborate economic analysis "tools" that can be used to assess economic sector marginal benefits and trade-offs surrounding buffer zone management. These tools are: benefit-cost analysis, marginal benefit assessment, and cost-effectiveness analysis. They can be used appropriately, and accurately, at the county or regional level.

Section 5 – References

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Appendix A

Review of Riparian Ecosystems Literature Citations

Appendix A
Review of Riparian Ecosystems Literature Citations. Communicated to the Ag Fish Water Agricultural Caucus from John Mankowski, WDFW and Steve Landino, NMFS, May 30, 2001.

This Appendix A. is a synopsis of the literature and evidence that the WDFW and NMFS use to support recommendations for maximum riparian buffer widths in Washington State's Agricultural Lands. We review the basis of the citations and comment on them from the perspective of Best Available Science.

These reports, other supporting citations and literature, form the basis of this Review of Science Recommendations for Agricultural Buffers for the Ag Fish Water Agricultural Caucus.

They are reviewed in the same sequence as collated by the originating agencies.

We were unable to review two sources directly, one was an REMM model in press (Appendix A.11) and the other was a paper by Murphy 1995 on effects of logging salmonid habitat in Alaska (Appendix A.8). We did review other research by this same author elsewhere and on this topic by other authors such as by S. Gregory Or.St.Univ.

Appendix A.1

Conservation Buffers to Reduce Pesticide Losses

Appendix A.1
United States Dept. of Agriculture-Natural Resources Conservation Service. 2000. Conservation Buffers to Reduce Pesticide Losses. Source available at: http://www.nrcs.usda.gov.

This NRCS report discusses several studies that have evaluated the effectiveness of buffer zones to trap pesticide field losses.

On key point that is made by the report is that pesticide field losses are largely occur at locations of heavy rainfall and pesticide use or where some types of irrigation practices are used. Water run-off is the measure that is being controlled by the buffer zones.

Another characteristic of the report is that it reviews technical studies almost exclusively conducted within the Southwest or Midwest.

The review of buffer sizes and conditions varies greatly, with some buffer in the 15-30 ft. width range and others much larger—as much as 164 ft. for multipurpose buffers. The authors note that buffer widths ranging from 16 to 59 ft. have been effective to filter out agri-chemicals depending on buffer types and land conditions.

For sediment trapping, the report acknowledges studies suggesting 15-30 ft. wide buffers as being adequate, while other studies recommended 50 ft. buffers, as a general rule.

In designing buffers, the report stresses that the buffer purpose must be defined and applied taking into account local conditions (land-use, soil composition, and climate conditions). For sedimentation problems, buffers of 20 ft. are deemed adequate, while if the focus is on nitrates and pesticides, wider buffers are recommended. But the key factor in designing buffers will be site-specific conditions.

The report also stresses that on-farm manages practices (best management practices) should be considered in designing buffer zones, as well as farm-specific economic conditions.

Appendix A.2

Ecological Issues in Floodplains and Riparian Corridors

Appendix A.2
Bolton, S. and J. Shellberg. 2001. Ecological Issues in Floodplains and Riparian Corridors. White Paper. Prepared by University of Washington, Center for Streamside Studies. Submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology, Washington Department of Transportation.

This report focuses on the ecological effects of channelization, channel confinement, and construction in riparian areas. As such, it really does not provide any information about the specific topic of riparian buffers in agricultural areas. The report makes no recommendations for riparian buffer zones. It does, however, discuss channel migration zones (CMZ). This is the area in which the stream is expected to move. The report reviews a number of definitions of the CMZ.

Appendix A.3

Forest Ecosystem Management: An Ecological, Economic, and Social Assessment

Appendix A.3

Forest Ecosystem Management Assessment Team. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Washington, D.C.: US Department of Agriculture, Forest Service; US Department of Commerce, National Oceanic and Atmospheric Administration, US Department of Interior, Bureau of Land Management, U.S. Fish and Wildlife Service, and National Park Service; and Environmental Protection Agency.

The Forest Ecosystem Management Assessment Team (FEMAT) was commissioned to formulate new management options to address the crisis caused by federal court bans timber harvest on federal lands with spotted owls and other listed species. Scientists from universities and agencies USFS, BLM, EPA, USFWS, NPS, NMFS, comprised the team.

FEMAT was instructed to identify management alternatives for establishing a network of late-successional/old-growth reserves and a prescription for the management of the intervening forestland. The Plan was to attain the greatest economic and social contributions from the forests but also meet the requirements of the Endangered Species Act, the National Forest Management Act, the Federal Land Policy Management Act, and the National Environmental Policy Act.

The management options incorporated conservation measures for the recovery of the identified listed species, with northern spotted owl as a guiding species. The area addressed by FEMAT is the range of the northern spotted owl within the United States, which includes western Washington, western Oregon, and northwestern California. The resulting stream buffer subscriptions were based on the life history needs of a multitude of species and their habitat structure but primarily driven by recovery needs of spotted owls. The Team was commissioned to formulate and assess the consequences of an array of management options that might solve timber cutting and other operation issues within the northern spotted owl range. The objectives were to produce management alternatives that would comply with existing laws and produce the highest contribution to economic and social wellbeing. Note: **This is considerably different need and goal for riparian buffer protection of salmonids in agricultural lands (emphasis AgFishWater Review).**

Each of the ten options contains reserve areas in which timber harvests are either not allowed at all or are limited, and areas outside of reserves (referred to as the Matrix) where most timber cutting occurs. The reserves are of two types: Late-Successional Reserves, encompassing older forests stands, and Riparian Reserves, consisting of protected strips along the banks of rivers, streams, lakes, and wetlands, which act as a buffer zone between the water and areas where cutting is allowed.

The forthcoming discussion will focus on salient Riparian Reserve issues.

All options contain some form of Riparian Reserves. Riparian Reserves are intended to address the habitat requirements for fish and other aquatic and riparian species. They also protect water quality, maintain appropriate water temperatures, and reduce siltation and other degradation of aquatic habitat that results from timber cutting on adjacent land. This degradation has been an especially serious product of past road building and cutting practices and is a contributing reason why certain fish species are now at risk of extinction.

Under different options, Riparian Reserves vary in width depending on the size of the body of water and the ecological importance of the watershed. Options 1 through 4 provide the greatest amount of riparian protection. Options 7 and 8 provide the least. The rest are in the middle of the range of protection.

The options recognize three categories of waters: (1) permanently flowing fish-bearing rivers, streams, lakes, and reservoirs; (2) permanently flowing nonfish-bearing streams, ponds, and wetlands larger than 1 acre; and (3) intermittent streams and wetlands smaller than 1 acre.

All options except Options 7 and 8 incorporate buffer widths that are a minimum of 300 feet on each side of the water for the first category of streams, and a minimum of 150 feet for permanently flowing streams of the second category. Option 7 buffers were established by Forest Service and the BLM and are generally narrower. Option 8 uses 75 foot buffers for the second category.

In addition, all options except Option 7 prescribe minimum buffer widths for intermittent streams and for small wetlands:
Options 1 and 4 use a buffer width of at least 100 feet for these areas.

Options 2, 3, 5, 6, 9, and 10 use a 100-foot minimum width for intermittent streams and certain Key Watersheds and a 50 foot minimum elsewhere. In Option 9 an effort was made to delineate the Late-Successional Reserves in Key Watersheds.

Option 8 uses a 25-foot minimum for all intermittent streams and small wetlands.

Option 7 is based on the plans of the Forest Service and the BLM. Those plans do not generally prescribe a minimum buffer for intermittent streams; where they do the buffer width is usually 25 feet.

Initially, under all options but 7, no harvest would be allowed in Riparian Reserves, and agencies would be required to minimize the impact of roads, cattle grazing, and mining activities. Prescriptions under Option 7 are less restrictive. The options that prescribe buffers allow for the adjustment of buffer widths and may allow some timber cutting after completion of watershed assessments.

In planning for ecosystem management and establishing Riparian Reserves to protect and restore riparian and aquatic habitat, the overall watershed condition and the suite of processes operating need to be considered in a watershed analysis. Watershed analysis is required in Key Watersheds before moving forward with all options except Option 7.

The FEMAT team predicted that increased levels of protection of old growth forests provided by larger reserve systems should foster an increased likelihood of successful persistence of organisms associated with late-successional and old-growth forest. **Note: This orientation is for the preservation of old growth tree habitat and is not directly applicable to secondary growth riparian forests of agricultural lands (emphasis AgFishWater Review).** FEMAT found that if a species did not fare well under a particular option its response generally improved under a more conservative option. This conclusion can be linked to agricultural buffers in a general fashion. It is arguable that more conservative options will allow a species to fare better in agricultural systems as well. However, the Team did identify species and situations where particular organisms or groups did not respond to the level of habitat protection provided.

Critical issues in management of aquatic resources are; (1) at-risk fish stocks and species; (2) stream, riparian, and wetlands habitat; (3) water quality; and (4) nonfish species of aquatic and riparian-dependent organisms.

The Team developed a set of options for management of aquatic and riparian ecosystems based on scientific understanding of the functional links between stream and wetland ecosystems and adjacent terrestrial vegetation. Streamside forests profoundly influence habitat structure and food resources of stream systems for lateral distances exceeding a tree height for many functions. Tree height distance away from the stream is a meaningful indicator that is crucial for providing aquatic habitat components, including wood recruitments and degree of shade. The Team defined site-potential tree height as the average maximum height of the tallest dominant trees (200 years or more) of a given site.

Riparian Reserves are portions of watersheds where riparian-dependent resources receive primary emphasis and where species standards and guidelines apply. Riparian Reserves include those portions of a watershed that are directly coupled to streams and rives, that is, the portions of a watershed that directly affect streams, stream processes, and fish habitats. Every watershed in National Forests and BLM Districts within the range of the northern spotted owl will have Riparian Reserves. Land allocated to Riparian Reserves status varies between options from 0.62 to 2.88 million acres.

In summary Options 1 and 4 had the greatest likelihood, 80 percent or greater, of attaining sufficient quality, distribution and abundance of habitat to allow the species populations to stabilize across federal land. The positive outlook for these options resulted from the relatively larger amount of area in Late-Succession Reserves and the Riparian Reserves.

Options 2, 3, 5, 6, 9, and 10 generally had a 60-70 percent likelihood of attaining an outcome where habitat for the seven species/groups of anadromous fish was sufficient to support quality spawning and rearing habitat well-distributed across federal lands. These options had a smaller likelihood of attaining this outcome than Options 1 and 4 because of less area in Late-Successional Reserves and the Riparian Reserves.

Option 7 and 8 were ranked low and the reduced likelihood was due to the reduced size of Riparian Reserves, particularly along intermittent streams.

A very applicable statement to the current project can be found in the FEMAT report, "(I)n considering the effects of any federal land management option on aquatic resources, two points are key: overharvest, disease, artificial propagation practices, and habitat impacts such as urbanization and agricultural practices have degraded and may continue to degrade aquatic habitat; and a plan for managing federal lands alone will not solve these problems. Ecosystem management cannot be successful without participation of all federal and nonfederal landowners and agencies that affect a watershed. The federal agencies must foster a partnership for ecosystem management with these entities to ensure conservation and prevent further degradation of the region's aquatic resources."

Another pertinent statement in the FEMAT (1993) report is that "(S)tructural components of stream habitat must not be used as management goals in and of themselves. No target management or threshold level for these habitat variables can be uniformly applied to all streams." The Team further concludes "while this approach (fixed-width buffers) is appealing in its simplicity, it does not follow for natural variation among streams."

The Team states, "(T)ree heights and slope distance provide ecologically appropriate metrics with which to establish Riparian Reserve widths. For example, tree height distance away from the stream is a better indicator of potential wood recruitment or degree of shade than is an arbitrary distance. Likewise, slope distance is a more meaningful ecological distance than horizontal distance."

The Oregon Forest Industries Council (OFIC) commissioned a review study of the scientific evidence supporting the FEMAT riparian shade effectiveness curve. The resulting 1999 report found that neither the scientific source nor the technical basis of the FEMAT shade curves could be independently verified. In addition, the data and curves from the FEMAT-referenced studies did not fit the published FEMAT shade relationship. The same study also found empirical data that indicated that the FEMAT curve underestimates the shade contribution from riparian vegetation. This 1999 OFIC-sponsored study focused on forest ecosystem buffer management. While this report would be helpful for the proposed project, it is by no means comprehensive for agricultural applications. There are three other riparian processes FEMAT cumulative effectiveness curves (Figure A.3.l): litter fall, root strength, and coarse woody debris. In addition, FEMAT produced six microclimate curves, which are relevant to the agricultural land management options.

Given this background information, it is not surprising the resulting FEMAT curves may not be applicable to lowland agricultural streams. FEMAT centered their research and management options on predominately coniferous late-successional, high gradient, forested areas. The form and function of coniferous forests are quite different from deciduous, low gradient riparian habitat of agricultural lands in Washington.

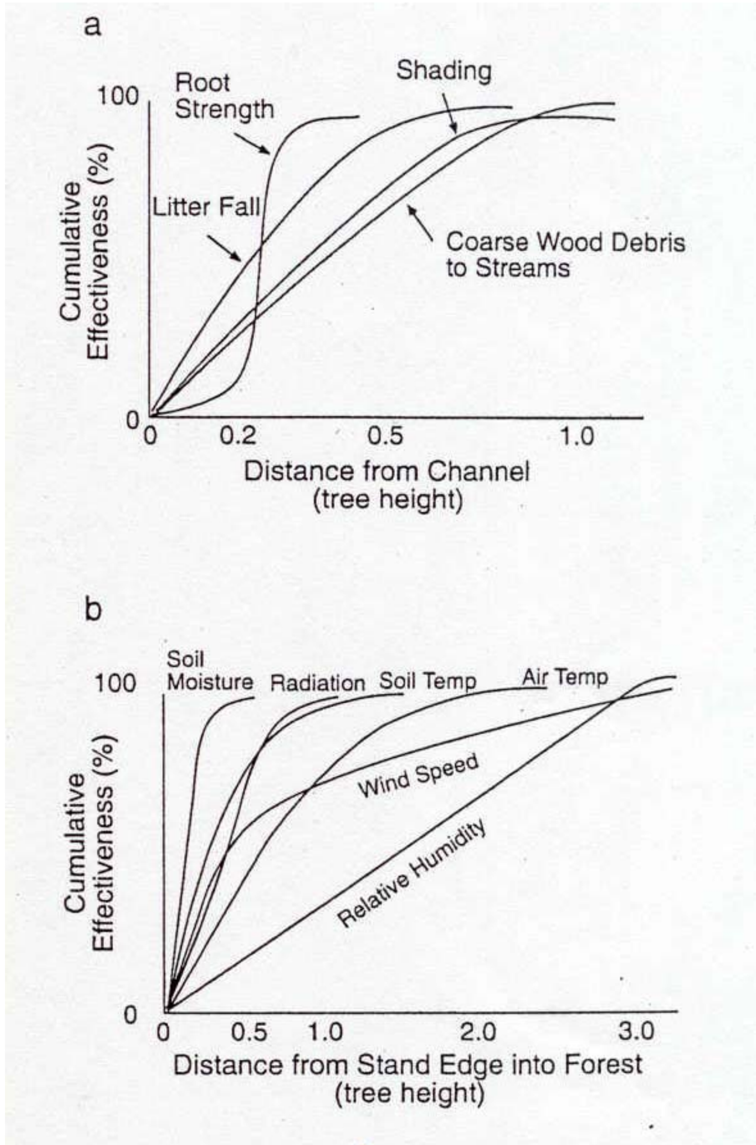

Figure A.3.1. See text for discussion.

At issue is the scientific basis for applying the FEMAT curve to lowland habitats and their relevancy to assessing agricultural impacts on aquatic systems. Much of the basis for concern is exactly how much impact agricultural uses are having on water quality and riparian/aquatic habitat. Although there is no denying that 100 years of agricultural improvements have changed local ecology, it is less clear that imposing maximum width stream buffers on every mile of agricultural stream channel stream buffers calibrated to coniferous forest removal is a cost-effective means of large woody debris recruitment. In fact, lowland riparian forests cannot supply the same quality of LWD of old-growth forests (see Bisson, 1987). Buffers may be needed in some places and may be the best means to restore some ecological functions; however, identifying the specific non-functioning parameter is important because each different function requires significantly different buffer accommodations. In some cases, alternatives to buffers may be better solutions. Specifically, the magnitude and location of agricultural habitats not meeting proper ecological functions is key to identifying the right buffer width or alternative strategy to achieve proper function if it is impaired. This is key in determining appropriate management actions: it is knowing which agricultural practices are actually contributing to the problem and whether a more direct type of mitigation might restore proper ecological function.   .

The Team concluded that the best approach would be through a continuing three phase process. The first phase involved development and assessment of management options for establishment of a network of late-successional/old-growth forest reserves and prescriptions for the management of the intervening forestland (i.e., the Matrix). The first phase also included selection of ten options and the completion of the procedures required by the National Environmental Policy Act (NEPA) (i.e., the Environmental Impact Statement). The second phase in the shift to ecosystem management is reinstituted forest planning – a process the Team feels must include federal, state, local government, and private interests if ecosystem management is to be achieved. The third phase involves implementation, monitoring, and adaptive management.

A key on-point biological objective involved aquatic and riparian habitats and wetlands on federal lands. These habitats are key to aquatic organisms including anadromous fish considered to be “at risk” of extinction. Because of this objective, riparian management options for habitat adjacent to streams were developed.

Appendix A.4

Final Environmental Impact Statement on Alternatives for Forest Practices Rules

Appendix A.4
Washington Forest Practices Board. 2001. Final Environmental Impact. Statement on Alternatives for Forest Practices Rules.

The Washington Forest Practices Board (Board) proposed to modify the Forest Practices Rules. The objectives of this proposal were to more fully address the impacts of forest practices on water quality, salmon habitat, and other aquatic and riparian sources. The primary impetus for the adoption of the rule proposal was the recent decline in fish stocks throughout much of Washington State and the large number of streams identified as having water quality problems.

The Board determined that changes in the Forest Practices Rules have the potential for significant adverse environmental impacts and therefore an Environmental Impact Statement was required under the State Environmental Policy Act to analyze the significant environmental impacts of the alternatives under consideration. This document is the Final EIS (FEIS). Note that the document that we reviewed is an executive summary of the FEIS and therefore only contains a brief summary description of the various alternatives and their impacts. The full EIS may contain more background information and justification based on science for the changes in the riparian buffer zones that are proposed.

The FEIS is organized into three parts. Chapter 1 provides the background and objectives. Chapter 2 provides the alternatives including the proposal. Chapter 3 provides an overview of the affected environment and environmental effects.

The document reports that four major discoveries/events support the need for revised Forest Practices Rules. The first area of need is related to water typing. "The water typing system used in Washington's Forest Practices Rules is based on beneficial uses, one of which is fish. Type 1, 2, and 3 Waters contain anadromous and resident fish, while Type 4 and 5 Waters do not. The water typing system has been in place for more than 20 years. Maps developed to implement the system were based on aerial photo interpretation with limited field verification. Over the years, field verification has provided data on actual fish use of waters, which has led to updated water type maps. While water types are continually reviewed and updated, large numbers of waters have not been field verified. In August 1994, Point-No-Point Treaty Council published a report, Stream Typing Errors in Washington Water Type Maps for Watersheds of Hood Canal and the Southwest Olympic Peninsula. Simultaneously, the Quinault Indian Nation and the Department of Fish and Wildlife were also reviewing water types in the southwest part of the Olympic Peninsula. Data from both studies indicated that seventy-two percent of Type 4 streams were actually Type 2 or 3 streams. Because water typing triggers riparian protection throughout the Forest Practices Rules, the definitions used to determine water types must reflect current knowledge about fish use and habitat."

"The second indication that Forest Practices Rules were inadequate was the prescriptive outcomes from watershed analysis. Watershed analysis is a process that reviews all forest lands within a watershed, finds sensitive resources within that watershed, and prescribes methods for protecting those sensitive resources. The watershed analysis rules were adopted in 1992 (chapter 222-22 WAC). Through the years, watershed analysis prescriptions for riparian areas have consistently been more stringent than the current

Forest Practices Rules. This led to the realization that the current rules were not doing an adequate job of protecting riparian functions."

"A third indicator of need for change in the Forest Practices Rules was the listing of many salmonid species on the federal and state threatened and endangered species lists. The lists include multiple races of chinook salmon, chum salmon, sockeye salmon, and steelhead, as well as the Columbia River bull trout. Other salmonids are being considered for listing. When a species is either federally or state-listed as threatened or endangered, the rules require DNR to consult with WDFW and make recommendations to the Forest Practices Board as to what, if any, modifications to the rules are necessary. The Forest Practices Board developed emergency salmonid rules, which were first put in place in May 1998. The maps which governed where the emergency salmonid rules applied were updated each time a new listing occurred."

"The fourth reason for changes was EPA's identification of over 660 Washington streams as water-quality-impaired under the Clean Water Act. Past forest practices in Washington are considered as one of a number of factors contributing to these listings."

Three alternatives are considered in detail in Chapter 2 of the FEIS.

Alternative 1
Alternative 1 entails continuing with the existing permanent Forest Practices Rules and does not include the revisions to these rules produced by the water typing, salmonid, or Forests and Fish Emergency Rules.

Alternative 2
Alternative 2 represents the alternative defined by the Forests and Fish Report (April 1999), as supplemented by House Bill 2091 and as subsequently refined. The provisions of the Forests and Fish Report and the Forests and Fish Emergency Rules are collectively referred to as the Forests and Fish Plan and are discussed in the previous section of this summary memorandum. The groups contributing to this report include Washington state agencies (Department of Natural Resources, Department of Ecology, Department of Fish and Wildlife), federal agencies (National Marine Fisheries Service, U.S. Environmental Protection Agency), the Colville Confederated Tribes, the Northwest Indian Fisheries Commission, The Washington State Association of Counties, the Washington Forest Protection Association, and the Washington Farm Forestry Association.

Alternative 3
Alternative 3 is representative of the alternatives produced by groups that were not among the authors of the Forests and Fish Report. Separate proposals were made by an environmental caucus (led by the Washington Environmental Council and the Audubon Society) and by the Muckleshoot Indian Tribe, Yakama Indian Nation, and Puyallup Indian Tribe. Elements of these proposals are incorporated into Alternative 3.

The following table provides a summary of provisions for each alternative applicable to the riparian buffer issue.

TABLE 1
SUMMARY DESCRIPTION OF THE ALTERNATIVES CONSIDERED IN DETAIL

Forestry Module Topic	Alternative 1 (No Action = Current Rules)	Alternative 2 (Proposed Action = Forests and Fish Report w/modification)	Alternative 3
Water Typing	***Five-type System*** Fish-bearing waters 1=shorelines of the state 2=generally > 20 feet 3=generally < 20 feet Non fish-bearing waters 4=generally > 2 feet 5=generally < 2 feet	***Three-type System*** Fish habitat waters S=shorelines of the state F=other fish habitat waters Non fish-habitat waters Np=perennial waters Ns=seasonal waters	***Three-type System*** Geomorphic-based Gradient = 0 – 20 % Gradient = 20 – 30 % Gradient = > 30 %
Riparian Habitat	Shorelines of the State (Type 1) Requirement of no more than 30% volume removal every 10 years within 200 feet of shoreline. Westside Fish Habitat (Type 1-3) 25 – 100 feet managed buffer Westside Non Fish Habitat (Type 4-5) Type 4: riparian leave tree areas sometimes required Type 5: no requirements	Shorelines of the State (Type S) Requirement of no more than 30% volume removal every 10 years within 200 feet of shoreline. Westside Fish Habitat (Type F) No management allowed inside channel migration zone (CMZ). Three zones: core, inner, outer Core Zone: no management Inner Zone: 2/3 SPTH buffers on streams <= 10 feet wide, managed with stand requirements; ¾ SPTH buffers on streams >10 feet wide with stand requirements Outer Zone: SPTH buffer with 10-20 trees/acre Westside Non Fish Habitat (Type N) Perennial: 50-foot no-cut buffer, sensitive sites; discontinuous with at least 50% buffer on length Seasonal: 30-foot equipment limitation zone	Shorelines of the State Requirement of no more than 30% volume removal every 10 years within 200 feet of shoreline. Westside Fish Habitat No management allowed inside channel migration zone (CMZ) or beaver habitat zone (BHZ). 200 feet additional managed buffer; only thin to improve riparian function through SEPA Westside Non Fish Habitat No management allowed inside channel disturbance zone (CDZ). In addition, the following buffers are added: Perennial: 100-foot continuous no-cut buffer Seasonal: 70-foot no-cut buffer

Forestry Module Topic	Alternative 1 (No Action = Current Rules)	Alternative 2 (Proposed Action = Forests and Fish Report w/modification)	Alternative 3
Riparian Habitat (continued)	Eastside Fish Habitat 30- to 300-foot managed buffer Eastside Non Fish Habitat Type 4: riparian leave tree areas sometimes required Type 5: no requirements Small Landowners None	Eastside Fish Habitat Three additional zones: core, inner, outer. Core: no management Inner: 70 or 100 feet; management with stand requirements Outer: SPTH buffer with 10, 15 or 20 trees/acre Eastside Non Fish Habitat Perennial: 50-foot managed buffer with uneven-aged management; discontinuous buffer with up to 300 ft. clearcut, but maximum of 30% length under even-aged management; plus 30-foot equipment limitation zone Seasonal: 30-foot equipment limitation zone Small Landowners Exemption from new rules for <20-acre parcels for landowners who own less than 80 acres of forested land; DNR can add 15% of stand volume to current riparian buffers	Eastside Fish Habitat 200 feet managed buffer; only can thin to improve riparian function through SEPA Eastside Non Fish Habitat Perennial: 100 feet continuous no-cut buffer Seasonal: 70-foot no-cut buffer Small Landowners Exemption from new rules for <20-acre parcels for landowners who own less than 80 acres of forested land; DNR can add 15% of stand volume to current riparian buffers
Unstable Slopes	Reviewed in forest practices application process SEPA trigger	Reviewed in forest practices application process; improved definitions, screens, training and field verification SEPA trigger Addresses public safety Identification of high hazard and moderate hazard landforms	Reviewed in forest practices application process; improved definitions, screens, training and field verification SEPA trigger Addresses public safety Identification of high hazard and moderate hazard landforms. Add all >80% planar slopes to definition of high hazard; no harvest on high hazard; additional 50-ft. buffer around high hazard slopes; all > 50% slopes classed as moderate hazard
Watershed Analysis	Mandatory for DNR as funding allows Voluntary for landowners Nine modules currently included Improved hydrology and water quality modules Prescriptions written for all modules	Mandatory for DNR as funding allows Voluntary for landowners Nine modules plus new ones Improved hydrology and water quality modules New cultural and restoration modules No prescriptions for riparian, mass wasting, and surface erosion.	Mandatory for DNR as funding allows Voluntary for landowners Nine modules plus new ones Improved hydrology and water quality modules Monitoring of forest practices in watersheds without watershed analysis. New cultural and restoration modules. No prescriptions for riparian, mass wasting, and surface erosion

Forestry Module Topic	Alternative 1 (No Action = Current Rules)	Alternative 2 (Proposed Action = Forests and Fish Report w/modification)	Alternative 3
Forest Pesticides	Current rules allow no chemicals in streams 50-foot buffer along streams 100-foot buffer adjacent to other properties 200-foot buffer adjacent to residences	No chemicals in streams or core or inner zones. Variable width buffer depending on equipment and wind conditions New BMPs	Protect plants of cultural value Require 50-foot buffer for hand application of chemicals Use of alternate plan for restoration of riparian functions
Hydrology	Rain-on-snow rule Eastside hydrology watershed analysis module	Rain-on-snow rule Eastside hydrology watershed analysis module	Rain-on-snow rule strengthened to limit harvest based on cumulative past harvest Eastside hydrology watershed analysis module

Chapter 3 summarizes the environmental impacts associated with each of the alternatives. The impacts reviewed are sediment delivery to streams, hydrology, riparian habitat, wetland habitat, water quality, fish, wildlife, risk of fire initiation, undiscovered cultural resources, and cumulative effects on the aquatic ecosystem.

Applicable conclusions to riparian buffers are discussed below.

Sediment

Under Alternative 1 the risk of fine and coarse sediment delivery to streams would be high. One reason given is the lack of riparian management zones (RMZs) on Type 4 and 5 streams. Alternative 2 is expected to produce a low to moderate risk of fine sediment delivery. The moderate rating is associated with the lack of RMZs along many steep headwater streams. The authors believe that Alternative 3 would produce a low risk of fine and coarse sediment delivery to streams because of the requirement for RMZs on all streams, including steep seasonal streams and channel disturbance zone buffers.

The applicability of this section to agricultural buffers is linked to the conclusion that increased riparian buffers decrease the delivery of coarse and fine sediment to streams.

Riparian Habitat

Alternative 1 would result in a high risk of diminished large woody debris (LWD) recruitment along fish-bearing streams and a very high risk along nonfish bearing streams.

The authors conclude that Alternative 2 appears to provide adequate protection for most riparian functions except those along many small streams that have no RMZs. In general, the risk of inadequate protection of riparian function appears to be higher for the eastside.

Alternative 3 would result in low risk of effects on LWD recruitment potential due to increased RMZ widths, addition of channel migration zones (CMZs), and a prohibition of harvest.

Again, the applicability of this document to agricultural buffers appears to be that RMZs and additional riparian protection measures are important to provide protection for riparian functions. The conclusion appears to be that as the RMZ increases more protection of riparian functions are provided.

Water Quality

Alternative 1 would result in a low to moderate risk of stream temperature increases along fish-bearing streams and a high risk along nonfish-bearing streams, a high risk of sediment-related effects on stream water quality, and a low to moderate risk of localized pesticide contamination of surface waters.

The authors believe that under Alternative 2 a possibility exists for a low risk of temperature increases in fish-bearing streams and a moderate to high risk in nonfish-bearing streams. Additionally, Alternative 2 is believed to result in a moderate risk of sediment water quality impacts in the short-term and a low to moderate risk in the long-term, however, the authors note that a moderate degree of uncertainty is associated with this conclusion.

Alternative 3 is thought to result in a low risk of temperature increase in all streams, a moderate risk of sediment water quality impacts in the short-term, and a low risk in the long term. Again, the authors note a moderate degree of uncertainty is associated with this conclusion.

Fish

Under Alternative 1, habitat degradation on private forest lands and eastside state forest lands would likely continue and contribute to further declines in listed fish species.

Alternative 2 would result in a low to moderate risk of continued habitat degradation over the short-term. Over the long-term, monitoring and adaptive management would result in reduction in this risk even further.

Alternative 3 would result in a low to very low risk of continued habitat degradation over the short-term. Over the long-term, monitoring and adaptive management would result in reductions in this risk even further.

Wildlife

Alternative 1 would result in high risk for amphibian microhabitat variables along larger streams and essentially no protection along smaller streams. This alternative would provide high risk associated with habitat for most other riparian species.

Alternative 2 would result in moderate risk for amphibian microhabitat variables along larger streams and high risk along smaller streams. This alternative would provide low to moderate risk associated with habitat for most other riparian species.

Alternative 3 would result in low risk for amphibian microhabitat variables along larger streams and moderate risk along high gradient streams. This alternative would provide low risk associated with habitat for most other riparian species.

Cumulative Effects

The rules under Alternative 1 are not protective enough to prevent cumulative effects in these watersheds.

Although the riparian, forest roads, and unstable slope rules under Alternative 2 would be substantially more protective than under Alternative 1, the authors conclude that they are unlikely to be protective enough to prevent cumulative effects in watersheds containing high levels of past harvest or other disturbances. In particular, a high degree of uncertainty exists regarding the potential for cumulative effects relative to the lack of RMZs on many perennial and all seasonal nonfish-bearing streams. This uncertainty is increased in watersheds with high levels of recent past harvest.

Under Alternative 3 the riparian rules would be substantially more protective than under Alternatives 1 or 2. Therefore, the authors conclude, the cumulative effects are unlikely, except in watersheds with the highest level of past harvest or other disturbances.

Overall, this document is useful because it provides an analysis and comparison of the Forests and Fish Plan’s provisions (Alternative 2) for possible effects on riparian buffers and the associated waterways with a less protective plan (Alternative 1) and a more protective plan (Alternative 3). The general trend in this analysis of effects is that larger RMZs provide more protection for riparian ecological functions.

Appendix A.5

Management Recommendations for Washington's Priority Habitats: Riparian

Appendix A.5
Knutson, K. L., and V. L. Naef. 1997. Management recommendations for Washington's Priority Habitats: Riparian. Wash. Dept. Fish and Wildl., Olympia. 181pp.

According to the executive summary for this report, "The Washington Department of Fish and Wildlife (WDFW) has developed statewide riparian management recommendations based on the best available science. Nearly 1,500 pieces of literature on the importance of riparian areas to fish and wildlife were evaluated, and land use recommendations designed to accommodate riparian-associated fish and wildlife were developed. These recommendations consolidate existing scientific literature and provide information on the relationship of riparian habitat to fish and wildlife and to adjacent aquatic and upland ecosystems. These recommendations have been subject to numerous review processes". Per our (AgFishWater) review of the controversy of Best Available Science elsewhere in this document, by definition therefore, this paper assumes that its recommendations are by fiat. There can be no other science. Unfortunately, the situation is far more equivocal.

"Recommendations on major land use activities commonly conducted within or adjacent to riparian areas are provided, including those relative to agriculture, chemical treatments, grazing, watershed management, roads, stream crossings and utilities, recreational use, forest practices, urbanization, comprehensive planning, restoration, and enhancement. Management recommendations for riparian areas are generalized for predictable application across the Washington landscape and include the following standard riparian habitat area (RHA) widths".

Standard recommended Riparian Habitat Area (RHA) widths for areas with typed and non-typed streams. If the 100-year floodplain exceeds these widths, the RHA width should extend to the outer edge of the 100-year floodplain.

Stream Type	Recommended RHA widths in meters (feet)
Type 1 and 2 streams; or Shorelines of the State, Shorelines of Statewide Significance	76 (250)
Type 3 streams; or other perennial or fish bearing streams 1.5-6.1 m (5-20 ft) wide	61 (200)
Type 3 streams; or other perennial or fish bearing streams <1.5 m (5 ft) wide	46 (150)
Type 4 and 5 streams; or intermittent streams and washes with low mass wasting* potential	46 (150)
Type 4 and 5 streams; or intermittent streams and washes with high mass wasting* potential	69 (225)

"Recommended RHA widths in this document only apply to riparian areas associated with streams and rivers. The widths should be applied to both sides of a stream or river, and width measurements should begin at the ordinary high water mark. The channels of some streams, particularly larger streams and rivers in broad, alluvial valleys, may migrate across the valley as a result of natural erosional and depositional processes; the area over which the channel is expected to migrate is called the channel migration zone. For these streams and rivers, RHA width measurements should begin at the edge of the channel migration zone".

The following are important additions to the recommended RHA widths:

- Larger RHA widths may be required where priority species occur; consult Appendix D for these widths.
- Add 30 m (100 ft) to the RHA's outer edge on the windward side of riparian areas with high blowdown potential.
- Extend RHA widths at least to the outer edge of unstable slopes along Type 4 and 5 waters in soils of high mass wasting potential.

The report states, "There is agreement in the literature that restricted use of riparian habitat is needed to retain the functions of aquatic and riparian ecosystems. Schaefer and Brown (1992) stated that width is one of the most important variables affecting riparian corridor functions. **However, there is less agreement on the specific width needed to protect riparian and stream habitat (O'Connell et al.1993) Nor is there agreement on which land use activities might be compatible with fish and wildlife in riparian habitat (our emphasis).** Recommendations to retain riparian areas are usually designed to retain specific functions (e.g., water quality and temperature) and rarely address the full range of ecological functions necessary to support fish and wildlife, as is the goal of these management recommendations".

"Recommended RHA widths are intended to encompass the full extent of riparian habitat associated with streams and rivers. Where appropriate, the RHA widths also include an additional area necessary to protect the RHA from windthrow or unstable slopes. In developed areas or areas where natural resources have been extensively modified, there may be man-made features or vegetation that do not resemble natural conditions within the recommended RHA. In these areas, the RHA width still provides an indication of the area that is influencing the stream system and the area that could potentially serve as fish and wildlife habitat, if it were restored. Recommended RHA widths generally include a zone of riparian vegetation plus a transition zone dominated by upland vegetation. Even though it may not be obvious that upland vegetation is part of riparian habitat, scientific studies clearly describe the critical function of transitional areas in maintaining riparian and aquatic systems (e.g., Gregory and Ashkenas 1990, Gregory et al. 1991)".

"Riparian habitat area widths are measured on the horizontal plane. They begin at the change in topography or vegetation that marks the ordinary high water line on each side of the active channel. Ordinary high water line is defined as the mark on the shores of all waters that will be found by examining the bed and banks and ascertaining where the presence and action of waters are so common and usual and so long continued in ordinary years, as to mark upon the soil or vegetation a character distinct from that of the abutting upland, provided that in any area where the ordinary high water line cannot be found, the ordinary high water line is the line of mean annual high water (approximated by a flood recurrence interval of 2.33 years) (WAC 220-110-020). The active channel is defined as all portions of the stream channel carrying water at bankfull flows (Thomas et al. 1993:279). The active channel will generally encompass meanderings, braids, and irregularities characteristic of larger streams and rivers (Gregory and Ashkenas 1990). For streams and rivers in channel migration zones, RHA width measurements should begin at the edge of the channel migration zone".

"Recommended RHA widths are to be applied to both sides of a stream. Recommended RHA widths are designed to retain fully functional riparian habitat. The Washington Department of Fish and Wildlife has not identified minimum widths because minimal conditions do not offer adequate habitat to support healthy fish and wildlife in the long run. With the current state of knowledge, no one can definitively say at what point each riparian function is lost. At the same time, WDFW recommendations are not to be considered maximums. Maximum protection from a fish and wildlife perspective would likely involve no development anywhere". In other words, maximum protection is recommended even though no knowledge of the point at which ecological function is 50%, 60% or even 95% restored. In a world of unlimited resources, such an approach is understandable. However, since the economic burden of such an approach belongs to others, and not WDFW, no consideration is apparently given to cost-effectiveness or cost-benefit or diminished returns. This is surprising since even the FEMAT curves, if taken on faith as accurate, show an asymptotic curve of diminished ecological benefits usually considerably closer to the stream bank than maximum benefits. When connected with the statement that these recommendations must be followed since they are defined by the authors as "Best Available Science", we arrive at WDFW's self-fulfilling syllogism that maximum buffer coverage is required because it is Best Available Science. Best Available Science is defined by WDFW as maximum ecological function.

"Beyond the standard recommended RHAs, it must be recognized that larger areas are needed by some wildlife species, including yellow-billed cuckoo, great blue heron, mule deer, elk, marten, osprey, and bald eagle (Gaines 1974, Thomas et al. 1979, Knight 1988, Freel 1991, Rodrick and Milner 1991). Larger RHA widths should be added to standard RHAs where these and other priority species require such increases".

"For RHAs to be effective in maintaining quality riparian and aquatic habitat, **they should be applied in all areas throughout Washington to the greatest extent possible (AgFishWater review emphasis—see discussion above regarding syllogisms).** The implementation of RHA protection should be combined with watershed analysis and planning to comprehensively address problems and solutions at the ecosystem level".

"Site-specific modifications to recommended RHAs can be made using *Habitat Characteristics Important to Fish and Wildlife* (p. 79 in report) as a guide. Important characteristics should be retained or restored in all riparian areas in order to provide suitable habitat for fish and wildlife".

The report includes examples of recommended riparian buffer widths from the literature. This summary is reproduced below.

Table 2. Examples of riparian habitat buffer recommendations found in the literature. Widths apply to each side of the stream.

Source	Recommended riparian buffer widths	Notes
Washington Department of Ecology (1985)	60 m (200 ft) buffer on all streams	Buffer to protect riparian ecosystem.
Gregory and Ashkenas (1990)	Class I Streams: 61 m (200 ft) ave., 46-122 m (150-400 ft) range Class II Streams: 30 m (100 ft) ave., 30-61 m (100-200 ft) range Class III Streams (stable): 23 m (75 ft) ave., 15-30 m (50-100 ft) range Class III Streams (unstable): 30 m (100 ft) ave., 23-38 m (75-125 ft) range	Recommendations for the Willamette National Forest, Oregon.
Johnson and Ryba (1992)	Recommends 15-30 m (50-100 ft) buffer to protect most stream functions. Reports buffer recommendations from the literature ranging from 3-200 m (10-656 ft).	Based on a literature review of buffer recommendations. Recommendations do not include wildlife habitat, only riparian functions to maintain instream habitat.
U.S. For. Serv. et al. (1993), Reeves and Sedell (1992)	Fish-bearing streams: outer edge of the 100-year floodplain, or the outer edge of riparian vegetation, or the distance equal to the height of 2 site-potential trees, or 92 m (300 ft), whichever is greatest. Permanently flowing non-fish-bearing streams: outer edge of the 100-year floodplain, or the outer edge of the riparian vegetation, or the distance equal to the height of 1 site-potential tree, or 46 m (150 ft), whichever is greatest. Intermittent streams: the extent of unstable or potentially unstable area, or the outer edge of riparian vegetation, or 30 m (100 ft), whichever is greatest.	Buffers are part of an Aquatic and Riparian Conservation Strategy. Buffers are recommended for areas within the range of the northern spotted owl, including western Washington and the east slope of the Cascades.
Washington State Forest Practices Board (1992)	Riparian Management Zones for western Washington: Type 1 and 2 water ($\geq$ 23 m): 30 m (100 ft) Type 1 and 2 water (<23 m): 23 m (75 ft) Type 3 water ($\geq$ 2 m): 15 m (50 ft) Type 3 water (<2 m): 8 m (25 ft) Riparian Management Zones for eastern Washington: Partial harvest units: 9-15 m (30-50 ft) Other harvest types: 9-91 m (30-300 ft)	These Riparian Management Zones are not 'no entry' zones as are most others reported in this table. Specific restrictions regarding the number of trees to leave during timber harvest are set forth in the Forest Practice Rules.
Cederholm (1994)	Based on Forest Practices Water Types: Types 1 and 2: 76 m (250 ft) Type 3 [2-6 m (5-20 ft) stream width]: 61 m (200 ft) Type 3 [<2 m (5 ft) stream width]: 46 m (150 ft) Types 4 and 5 (low mass wasting potential): 46 m (150 ft) Types 4 and 5 (high mass wasting potential): 69 m (225 ft)	Buffers designed for western Washington riparian ecosystems. Add 50 ft buffer on windward side in area of high blowdown potential. Provide additional buffers to include entire unstable slope on Type 4 and 5 streams.
Ecosystem Standards Advisory Committee (1994)	Riparian Management Zones, defined as: Type 1-4 waters - 30 m (100 ft) Type 5 waters - 15 m (50 ft)	Developed as ecosystem standards for state-owned agricultural and grazing land under HB1309. These recommendations were based on an earlier draft of this PHS Management Recommendation document.

Regarding variable riparian widths, the report states, "While variable riparian habitat widths may allow landowners greater flexibility, sufficient information does not currently exist to provide variable width recommendations that adequately accommodate the extreme variability of riparian widths, land uses, and fish and wildlife communities across the Washington landscape. Therefore, any application of variable riparian widths must first include additional site-specific and watershed-level studies".

The report includes specific recommendations for agriculture. "Agricultural activities may contribute significantly to riparian and instream habitat degradation locally and across the landscape. A shift from conventional to sustainable agricultural practices would reduce or eliminate impacts to riparian and aquatic habitats and their fish and wildlife communities. Protection of RHAs, conservation tillage, use of cover crops, integrated pest management, use of non-chemical alternatives to pesticides, and alternative irrigation systems that reduce water use, erosion, and return flows are all techniques that should be explored and implemented across the landscape (Grue et al. 1989). Below are recommendations for protecting riparian and stream habitat in agricultural areas. Also, see the recommendations regarding grazing (p. 97) and chemical treatments (p. 104). The Washington Department of Fish and Wildlife recommends that farmers seek further assistance from local soil scientists, fish and wildlife biologists, and agricultural professionals in order to develop more specific agricultural activity plans using the guidelines presented here".

"Provide a buffer of natural vegetation between perennial or intermittent stream courses and cropland of 61 m (200 ft) or the above recommended RHA width, whichever is greatest. If cropland currently exists within riparian areas, explore ways to cease farming in that area and pursue restoration and revegetation with native riparian plants. See the section on *Restoration and Enhancement* (p. 113) and seek assistance from the Natural Resources Conservation Service or the Washington Department of Fish and Wildlife".

"In all agricultural areas, use techniques to eliminate or minimize soil erosion. Such techniques include: 1) conservation cropping systems (e.g., cover crops and conservation tillage); 2) selection of crops that hold soil and have high ground cover; 3) harvest techniques that minimize soil disturbance; 4) maintenance of continuous plant cover to the greatest extent possible; and 5) cultivation and harvest techniques that reduce the time that the soil is bare. Use drip irrigation or lateral piping rather than sheet or rill irrigation to reduce sedimentation and water consumption (P. Harvester, pers. comm.)".

Other recommendations for agriculture include pursue alternatives to harmful fertilizers in uplands, increase efficiency of water use, treat agricultural waste water, and limit accumulations of animal wastes near riparian habitat.

The report includes an appendix that summarizes the riparian habitat buffer widths needed to retain various habitat functions. It is reproduced below.

Appendix C. Riparian habitat buffer widths needed to retain various riparian habitat functions as reported in the literature, organized by riparian habitat function.

Riparian habitat function	Perpendicular distance from stream in meters (feet)	Source
WATER TEMPERATURE CONTROL		
60-80% shading	11-38 (35-125)	Brazier et al. 1973
	11-37 (35-120)	Johnson and Ryba 1992
	12 (39)	Corbett and Lynch 1985
	15-30 (49-100)	Hewlett and Fortson 1982
	18 (59)	Moring 1975
50-100% shading	18-38 (60-125)	U.S. Forest Service et al. 1993
	30 (100)	Lynch et al. 1985
	30 (100)	Beschta et al. 1987
	30 (100)	Johnson and Ryba 1992
	30-43 (100-141)	Jones et al. 1988
80% shading	46 (151)	Steinblums et al. 1984
LARGE WOODY DEBRIS		
	30 (100)	Murphy and Koski 1989
	31 (103)	Bottom et al. 1983
	45 (148)	Harmon et al. 1986
	46 (150)	McDade et al. 1990
	46 (150)	Robison and Beschta 1990
	50 (165)	Van Sickle and Gregory 1990
	55 (180)	Thomas et al. 1993
FILTER SEDIMENTS		
75% sediment removal	30-38 (100-125)	Karr and Schlosser 1977
90% of sediment removal at 2% grade	30 (100)	Johnson and Ryba 1992
Sediment removal	30 (100)	Erman et al. 1977, Moring et al 1982, Lynch et al 1985
	61 (200)	Terrell and Perfetti 1989
50% deposition	88 (289)	Gilliam and Skaggs 1988
Effective control of non-channelized sediment flow	60-91 (200-300)	Belt et al. 1992
FILTER POLLUTANTS		
Nutrient reduction	4 (13)	Doyle et al. 1977
Minimum	10 (33)	Petersen et al. 1992
	15 (49)	Castelle et al. 1992
	16 (52)	Jacobs and Gilliam 1985

Riparian habitat function	Perpendicular distance from stream in meters (feet)	Source
Nutrient removal using the multi-species riparian buffer strip system described by the authors	20 (66)	Schultz et al. 1995
Remove fecal coliforms	30-43 (100-141)	Jones et al. 1988
	30 (100)	Grismer 1981
	30 (100)	Lynch et al. 1985
Nitrates removed to meet drinking water standards	30 (100)	Johnson and Ryba 1992
Nutrient pollution in forested riparian areas	30 (100)	Terrell and Perfetti 1989
Nutrient removal	36 (118)	Young et al. 1980
Pesticides and animal waste	61 (200)	Terrell and Perfetti 1989
Nutrient pollution in herbaceous or cropland riparian areas	183 (600)	Terrell and Perfetti 1989
EROSION CONTROL		
Bank erosion control	30 (100)	Raleigh et al. 1986
High mass wasting area	38 (125)	Cederholm 1994
MICROCLIMATE INFLUENCE		
In forested ecosystem	61-122 (200-399)	Chen et al. 1990
	160 (525)	Harris 1984, Franklin and Forman 1987
WILDLIFE HABITAT		
General wildlife habitat	23 (75)	Mudd 1975
	9-201 (30-660)	Johnson and Ryba 1992
	61 (200)	Zeigler 1992
Species sensitive to disturbance	25 (82)	Croonquist and Brooks 1993
Aquatic insects	30 (100)	Erman et al. 1977
Benthic invertebrates - food supply	30 (100)	Erman et al. 1977
Macroinvertebrate density	30 (100)	Newbold et al. 1980
Macroinvertebrate diversity	30 (100)	Gregory et al. 1987
Riparian invertebrates	30 (100)	Erman et al. 1977, Roby et al. 1977, Newbold et al. 1980
Brook trout	30 (100)	Raleigh 1982
Chinook salmon	30 (100)	Raleigh et al. 1986
Cutthroat trout	30 (100)	Hickman and Raleigh 1982
Rainbow trout	30 (100)	Raleigh et al. 1984
Reptiles and amphibians	30-95 (100-312)	Rudolph and Dickson 1990

Riparian habitat function	Perpendicular distance from stream in meters (feet)	Source
Reptiles and amphibians	30 (100)	Rudolph and Dickson 1990
Birds	75-200 (246-656)	Jones et al. 1988
Full complement of birds	127 (417)	Sedgewick and Knopf 1986
	125 (410)	Croonquist and Brooks 1993
Nest predation reduced	100 (328)	Temple 1986
Forest interior birds only occur in corridors wider than 50 m	50 (164)	Tassone 1981
Minimum riparian width to sustain forest dwelling birds	60 (200)	Darveau et al. 1995
Minimum distance needed to support area-sensitive neotropical migrant birds	100 (328)	Keller et al. 1993
Distance needed to maintain functional assemblages of common neotropical migratory birds	100 (328)	Hodges and Krementz 1996
Great blue heron feeding	100 (328)	Short and Cooper 1985
Great blue heron nesting	250 (820)	Short and Cooper 1985
	250-300 (820-984)	Parker 1980, Short and Cooper 1985, Vos et al. 1985
Wood duck nesting	80 (262)	Gilmer et al. 1978
	183 (600)	Grice and Rogers 1965, Sousa and Farmer 1983
	200 (656)	Lowney and Hill 1989
Harlequin nesting	50 (164)	Cassirer and Groves 1990
Bald eagle buffer from human disturbance	121 (396)	Grubb 1980
Bald eagle disturbance during feeding	200 (656)	Skagen 1980
Bald eagle feeding areas	75-100 (246-328)	Stalmaster 1980
Bald eagle nesting	100 (328)	Small 1982
Bald eagle perching	50 (164)	Stalmaster 1980
Osprey nesting - no cut zone	61 (200)	Zarn 1974, Westall 1986
Pheasant and quail, eastern Washington	23 (75)	Mudd 1975
Mourning dove	15 (50)	Mudd 1975
Belted kingfisher roosts	30-61 (100-200)	Prose 1985
Downy woodpecker	15 (50)	Cross 1985
Hairy woodpecker	40 (133)	Stauffer and Best 1980
Pileated woodpecker and some neotropical migrants	15-23 (50-75)	Triquet et al. 1990
Pileated woodpecker nesting	150-183 (492-600)	Conner et al. 1975, Schroeder 1983

Riparian habitat function	Perpendicular distance from stream in meters (feet)	Source
Pileated woodpecker nesting	100 (328)	Small 1982
Black-capped chickadee	15 (50)	Cross 1985
White-breasted nuthatch	17 (57)	Stauffer and Best 1980
Red-eyed vireo	40 (133)	Stauffer and Best 1980
Warbling vireo nesting	90 (295)	Gilmer et al. 1978
Spotted towhee breeding populations	200 (656)	Stauffer and Best 1980
Brown-headed cowbird penetration from edge	240 (787)	Gates and Giffin 1991
Large mammals	100 (328)	Jones et al. 1988
Small mammals	67-93 (220-305)	Jones et al. 1988
	12-70 (39-230)	Cross 1985
	67 (220)	Cross 1985
Dusky shrew food and cover	183 (600)	Clothier 1955
Beaver	30-100 (100-328)	Allen 1983
Beaver foraging	100 (328)	Allen 1983
Fisher travel corridor	183 (600)	Freel 1991
Marten food and cover	61 (200)	Spencer 1981
Marten travel corridor	92 (300)	Freel 1991
Mink	100 (328)	Melquist et al. 1981, Allen 1986
	200 (656)	Melquist et al. 1981
Red fox, fisher, marten	100 (328)	Small 1982
Deer, Eastern Washington	23 (75)	Mudd 1975
Deer and elk cover	61 (200)	Mudd 1975
INSTREAM HABITAT		
Minimal maintenance of most functions	15-30 (50-100)	Johnson and Ryba 1992

Mean buffers:*

Temperature Control	27 m (90 ft)	Erosion Control	34 m (112 ft)
Large Woody Debris	45 m (147 ft)	Windthrow Protection	15 m (50 ft)
		Microclimate Influence	126 m (412 ft)
Filter Sediments	42 m (138 ft)	Wildlife Habitat	88 m (287 ft)
Filter Pollutants	24 m (78 ft)	Instream Habitat	15-30 m (50-100 ft)

* If a range of values was reported in the literature, the median of that range was used to calculate the means.

Appendix A.6

An Ecosystem Approach to Salmonid Conservation

Appendix A.6

Spence, B.C., G.A. Lomnicky, R.M. Hughes, and R.P. Novitzki. 1996. An Ecosystem Approach to Salmonid Conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR.

The document is organized generally into three parts. Chapters 1-10 (Part I) provide the technical foundation for understanding salmonid conservation principles from an ecosystem perspective. They discuss the physical, chemical, and biological processes operating across the landscape, within riparian areas, and in aquatic ecosystems; these processes ultimately influence the ability of streams, rivers, and estuaries to support salmonids. Specific habitat requirements of salmonids during each life stage are detailed. They then review the effects of land-use practices on watershed processes and salmonid habitats, focusing on the impacts of logging, grazing, farming, mining, and urbanization on hydrology, sediment delivery, channel morphology, stream temperatures, and riparian function. An overview is presented on the importance of ocean variability in determining production of anadromous salmonids and the implications of this variability on restoration of freshwater habitats of salmonids. Next, land-use practices that minimize impacts to salmonids and their habitats are discussed followed by a brief review of Federal laws that pertain to the conservation of salmonids on private lands. The Technical Foundation concludes with a review of strengths and weaknesses of existing programs for monitoring aquatic ecosystems; this chapter provides the basis for monitoring recommendations presented in Part II.

Chapters 11-16 (Part II) provide a general conceptual framework for achieving salmonid conservation on nonfederal lands in the Pacific Northwest, as well as specific guidelines for the development of Habitat Conservation Plans (HCPs) pursuant to the Endangered Species Act. Included in this discussion is an evaluation of the effectiveness of State rules for riparian management to protect specific processes that directly affect aquatic habitats. Compliance and assessment monitoring strategies for HCPs and other conservation efforts are proposed. The document concludes with a suggested strategy for implementing salmonid conservation efforts on nonfederal lands. An appendix (the third part) lists sources of data that landowners and agencies may find useful in developing and evaluating habitat conservation plans. Over 1100 sources are cited within this document and listed in the references section.

This is a long report that covers a great deal of material. Salient conclusions regarding riparian buffer zones in agricultural areas are summarized below.

The overall recommendation of the report with regards to buffers is, "We recommend that habitat conservation plans and other conservation agreements include a comprehensive plan for protecting riparian areas along all fish-bearing and nonfish-bearing streams, including ephemeral channels. Riparian buffers should be established for all land use types and should be designed to maintain the full array of ecological processes needed to create and maintain favorable conditions through time. Consideration should also be given to protecting microclimatic conditions to ensure the persistence of vegetation communities and, where applicable, other riparian-dependent terrestrial and semi-aquatic species."

The report includes a literature review on riparian buffers for each of the ecological processes identified as being critical to riparian zones. The ecological functions of riparian zones are stream shading, LWD recruitment, fine organic litter recruitment, bank stabilization, sediment control, dissipation of nutrients and other dissolved materials, They specifically describe the literature for forested lands as well as other land types, when available.

For stream shading, the report concludes, "The apparent consensus that buffers exceeding 30 m are needed for stream shading has been based largely on studies in the Cascade and Coast ranges. There is little published information regarding buffer widths needed to provide natural levels of shade for streams in eastside forest, rangeland, and agricultural systems… More research on riparian influences on shading for all ecosystems east of the Cascades is needed before specific criteria can be recommended; however, in most instances, buffer widths designed to protect other riparian functions (e.g. large woody debris (LWD) recruitment) are likely to be adequate to protect stream shading".

Because of the importance of LWD recruitment as a criterion for evaluating riparian buffers, we have included the entire section of the report of recommendations for buffers related to LWD.

> <u>LWD Recruitment.</u> Large wood enters stream channels by a variety of mechanisms, including toppling of dead trees, windthrow, debris avalanches, deep-seated mass soil movements, undercutting of streambanks, and redistribution from upstream (Swanson and Lienkamper 1978). Most assessments of buffer widths required for maintaining natural levels of large wood have considered only wood delivered by toppling, windthrow, and bank undercutting. Yet in some systems, wood delivered from upslope areas (via mass wasting) or upstream reaches (via floods or debris torrents) may constitute a significant fraction of the total wood present in a stream reach. In attempting to identify sources of large wood pieces in 39 stream reaches, McDade et al. (1990) failed to account for more than 47% of the woody debris pieces, suggesting that upslope and upstream sources potentially may be quite important. These mechanisms of delivery are more difficult to model, thus the discussion below focuses on recruitment from the immediate riparian zone. Nevertheless, in evaluating habitat conservation plans, consideration should be given to potential recruitment of wood from upslope areas and nonfish-bearing channels.
>
> The potential for a tree or portions of a tree to enter the stream channel by toppling, windthrow, or undercutting is primarily a function of slope distance from the stream channel in relation to tree height and slope angle. Consequently, the zone of influence for large wood recruitment is defined by the particular stand characteristics rather than an absolute distance from the stream channel or floodplain. Other factors, including slope and

prevailing wind direction, may influence the proportion of trees that fall in the direction of the stream channel (Steinblums et al. 1984; Robison and Beschta 1990b; McDade et al. 1990); however, if the goal is to maintain full recruitment of large wood to the channel, then protection of all trees within the zone of influence is desirable.

FEMAT (1993) concluded that the probability of wood entering the active stream channel from greater than one tree height is generally low (see Figure 3-2). Exceptions occur in alluvial valleys, where stream channels may shift in response to sediment deposition and high flow events. Two models of large wood recruitment also assume that large wood from outside of one tree height seldom reaches the stream channel (Van Sickle and Gregory 1990; Robison and Beschta 1990). Murphy and Koski (1989) found that 99% of all identified sources of LWD were within 30 m of the stream channel in hemlock and Sitka spruce forests of southeastern Alaska with site potential tree heights of approximately 40 m (131 ft) (M. Murphy, personal communication). Their study defined LWD as pieces greater than 3 m length and 10 cm diameter and thus excluded smaller fractions classified as large wood in other studies. In addition, because trees far from the stream channel generally contribute smaller individual pieces (i.e., the tops of trees) that are more easily transported downstream, the authors' abilities to identify sources likely decreased with increasing distance from the channel. Consequently, protecting all LWD recruitment may require slightly larger buffer zones. McDade et al. (1990) examined LWD recruitment to streams at 37 sites in the Cascade and Coast Ranges of Oregon and Washington and found that source distances were as far as 55 m in old-growth (> 200 years) coniferous forests and 50 m in unmanaged, mature (80-200 year old) conifer stands. Tree heights averaged 57.6 m in old-growth stands and 48 m in mature stands; thus, source distances were approximately equal to one site-potential tree height. In this study, woody debris was defined as pieces greater than 1 m length and 0.1 m diameter at the small end. Cederholm (1994) reviewed the literature regarding recommendations of buffer widths for maintaining recruitment of LWD to streams and found most authors recommended buffers of 30-60 m for maintaining this function. In summary, most recent studies suggest buffers approaching one site-potential tree height are needed to maintain natural levels of recruitment of LWD.

An additional consideration in determining appropriate activities in riparian zones relative to large wood recruitment is the potential size distribution of LWD. Murphy (1995) notes that larger pieces of wood form key structural elements in streams, serving to retain smaller debris that would otherwise be transported downstream during high flow events. Bisson et al. (1987) suggest that the size of these key pieces is approximately 30 cm or more in diameter and 5 m in length for streams

> less than 5 m in width and 60 cm or more in diameter and 12 m in length for streams greater than 20 m in width.
>
> For making Endangered Species Act determinations of effect, NMFS (1985c) uses large-size fractions of wood to define properly functioning habitats. These key pieces are defined as greater than 60 cm in diameter and 15 m in length for westside systems and greater than 30 cm in diameter and 11 m in length for eastside systems. Consequently, riparian protection plans need to ensure not only an appropriate amount or total volume of wood, but pieces of sufficient size to serve as "key pieces" (Murphy 1995).

For fine organic litter, the ManTech report states, "in most cases buffers designed to protect 100% of LWD recruitment will likely provide close to 100% of small organic litter as well." For bank stabilization, the report states that, "in most instances, vegetation immediately adjacent to the stream channel is most important in maintaining bank integrity, however, in wide valleys with shifting streams vegetation throughout the floodplain may be important over longer time periods." They cite FEMAT (1993) conclusions that, "most of the stabilizing influence of root structure is probably provided by trees within 0.5 potential tree height of the stream channel. Consequently, buffer widths for protecting other riparian functions are likely adequate to maintain bank stability".

For sediment control, they concluded that, because of the high degree of variability in the effectiveness of buffers, "we cannot draw any definitive conclusions regarding buffer widths required for sediment control. On gentle slopes, buffers of 30 m may be sufficient to filter sediments, whereas on steeper slopes, buffers of 90 m or more may be needed. In addition, riparian buffers are most effective in controlling sediments from sheet erosion and have less influence on sediments that reach the stream channels via channelized flow… We suggest that, except on steep slopes, buffers designed to protect other riparian functions will generally control sediment to the degree that they can be controlled by riparian vegetation. It is essential however, that riparian protection be complemented with practices for minimizing sediment contributions from outside areas"

Regarding nutrients and other dissolved materials, the review of the literature indicates that, "those studies that have been published indicate substantial variability in the effectiveness of buffer strips in controlling nutrient inputs… For rangelands, agricultural systems, and urban areas, we believe current understanding is insufficient to make specific buffer recommendations. The review of Johnson and Ryba (1992) suggest that buffers for nutrient control on forest and grasslands range from approximately 4 – 42 m, but that substantially wider buffers are needed to control nutrients and bacteria (fecal coliform) from feedlot runoff. We recommend that buffer widths for nutrient and pollution control on these lands be tailored to site-specific conditions, including slope, degree of soil compaction, vegetation characteristics, and intensity of land use. In many instances, buffer widths designed to protect LWD recruitment and shading may be adequate to prevent excessive nutrient pollution concentrations. However, where land use activity is especially intense, buffers for protecting nutrient and pollutant inputs may need to be wider…”

The final recommendations for riparian buffers in agricultural areas are, “riparian buffers are recommended for all permanent streams on agricultural lands that support salmonids, as well as ephemeral streams that influence salmonid habitats downstream. The dimensions of riparian buffers should depend on the specific ecological functions for which protection is desired (see above discussion). Use of agricultural machinery within the riparian zone or disturbance to vegetation and soils within the riparian zone should be avoided. Where channels have been degraded by agricultural activities, planting of riparian vegetation native to the region is recommended. Conservation can be further enhanced by retiring converted wetlands from agriculture”.

Appendix A.7

Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale

Appendix A.7
National Marine Fisheries Service, Environmental and Technical Services Division, Habitat Conservation Branch. 1996. Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale.

This document contains two primary parts, a matrix which is designed to summarize important environmental parameters and levels of condition and a checklist, which is used for determining the current condition of the environment and the potential effects of an action on the current environmental condition. The matrix is of interest to us for evaluating riparian buffers in agricultural lands.

This document does not include standards and guidelines for specific management actions. That is, it does not include specific requirements for riparian buffer zone widths. It also does not prohibit any particular activities in riparian buffer zones. What it does is define a "properly functioning" aquatic ecosystem in terms of "indicators".

The matrix is reproduced below in Table 1. There are a number of "pathways" and "indicators" that can be influenced by human activities in riparian zones, such as water temperature, streambank condition, sediment/turbidity, large woody debris, and others. The matrix describes what a properly functioning aquatic ecosystem would have for each of these indicators. For example, the matrix shows a properly functioning ecosystem would have a temperature between 50 – 57 ^{o}F, less than 12% fines in gravel, and low turbidity. Riparian buffers are one tool that could be used to restore or maintain these qualities.

In addition, one of the "indicators" listed is riparian reserves. A properly functioning riparian reserve is described as, "[a] riparian reserve system that provides adequate shade, large woody debris recruitment, and habitat protection and connectivity in all subwatersheds, and buffers or includes known refugia for sensitive aquatic species (>80% intact), and/or for grazing impacts; percent similarity of riparian vegetation to the potential natural community/composition >50%". No definitions are provided as to what constitutes "adequate shade". There is no quantification of the requirement for large woody debris recruitment. There is also no explanation of how to determine if the refuge for sensitive aquatic species is 80% intact. The reference that is cited for this indicator is:

Winward, A.H. 1989. Ecological Status of Vegetation as a base for Multiple Product Management. Abstracts 42nd Annual Meeting, Society for Range Management, Billings, MT. Denver, Colorado, Society for Range Management: p 277.

Unfortunately, this document has some weaknesses. The indicators of properly functioning ecosystems are defined very vaguely in many cases. Even where the indicators include a quantitative standard there is room for interpretation. For example, the temperature indicator is undefined. Is it a maximum daily temperature, a mean daily temperature, or some other metric? In addition, the matrix, particularly the indicators for large woody debris and riparian reserves, may not be applicable to ecosystems that are not forested, particularly if the historic condition was grassland.

Overall, this document has very limited usefulness for evaluating the effectiveness of any particular standard for riparian buffers on agricultural lands. It provides no scientific background that could be used to develop a standard for riparian buffers.

TABLE 1. MATRIX of PATHWAYS AND INDICATORS

(Remember, the ranges of criteria presented here are not absolute, they may be adjusted for unique watersheds. See p. 3)

PATHWAY	INDICATORS	PROPERLY FUNCTIONING	AT RISK	NOT PROPERLY FUNCTIONING
Water Quality:	Temperature	50-57° F[1]	57-60° (spawning) 57-64° (migration &rearing)[2]	> 60° (spawning) > 64° (migration & rearing)[2]
	Sediment/ Turbidity	< 12% fines (<0.85mm) in gravel[3], turbidity low	12-17% (west-side)[3], 12-20% (east-side)[2], turbidity moderate	>17% (west-side)[3], >20% (east side)[2] fines at surface or depth in spawning habitat[2], turbidity high
	Chemical Contamination/ Nutrients	low levels of chemical contamination from agricultural, industrial and other sources, no excess nutrients, no CWA 303d designated reaches[5]	moderate levels of chemical contamination from agricultural, industrial and other sources, some excess nutrients, one CWA 303d designated reach[5]	high levels of chemical contamination from agricultural, industrial and other sources, high levels of excess nutrients, more than one CWA 303d designated reach[5]
Habitat Access:	Physical Barriers	any man-made barriers present in watershed allow upstream and downstream fish passage at all flows	any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at base/low flows	any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at a range of flows
Habitat Elements:	Substrate	dominant substrate is gravel or cobble (interstitial spaces clear), or embeddedness <20%[2]	gravel and cobble is subdominant, or if dominant, embeddedness 20-30%[2]	bedrock, sand, silt or small gravel dominant, or if gravel and cobble dominant, embeddedness >30%[2]
	Large Woody Debris	Coast: >80 pieces/mile >24"diameter >50 ft. length[4]; East-side: >20 pieces/ mile >12"diameter >35 ft. length[2]; and adequate sources of woody debris recruitment in riparian areas	currently meets standards for properly functioning, but lacks potential sources from riparian areas of woody debris recruitment to maintain that standard	does not meet standards for properly functioning and lacks potential large woody debris recruitment
	Pool Frequency channel width # pools/mile[6] 5 feet 184 10 " 96 15 " 70 20 " 56 25 " 47 50 " 26 75 " 23 100 " 18	meets pool frequency standards (left) and large woody debris recruitment standards for properly functioning habitat (above)	meets pool frequency standards but large woody debris recruitment inadequate to maintain pools over time	does not meet pool frequency standards
	Pool Quality	pools >1 meter deep (holding pools) with good cover and cool water[3], minor reduction of pool volume by fine sediment	few deeper pools (>1 meter) present or inadequate cover/temperature[3], moderate reduction of pool volume by fine sediment	no deep pools (>1 meter) and inadequate cover/temperature[3], major reduction of pool volume by fine sediment
	Off-channel Habitat	backwaters with cover, and low energy off-channel areas (ponds, oxbows, etc.)[3]	some backwaters and high energy side channels[3]	few or no backwaters, no off-channel ponds[3]
	Refugia (important remnant habitat for sensitive aquatic species)	habitat refugia exist and are adequately buffered (e.g., by intact riparian reserves); existing refugia are sufficient in size, number and connectivity to maintain viable populations or sub-populations[7]	habitat refugia exist but are not adequately buffered (e.g., by intact riparian reserves); existing refugia are insufficient in size, number and connectivity to maintain viable populations or sub-populations[7]	adequate habitat refugia do not exist[7]
Channel Condition & Dynamics:	Width/Depth Ratio	<10[2,4]	10-12 (we are unaware of any criteria to reference)	>12 (we are unaware of any criteria to reference)
	Streambank Condition	>90% stable; i.e., on average, less than 10% of banks are actively eroding[2]	80-90% stable	<80% stable
	Floodplain Connectivity	off-channel areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession	reduced linkage of wetland, floodplains and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession	severe reduction in hydrologic connectivity between off-channel, wetland, floodplain and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly

Flow/Hydrology:	Change in Peak/ Base Flows	watershed hydrograph indicates peak flow, base flow and flow timing characteristics comparable to an undisturbed watershed of similar size, geology and geography	some evidence of altered peak flow, baseflow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography	pronounced changes in peak flow, baseflow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography
	Increase in Drainage Network	zero or minimum increases in drainage network density due to roads[8,9]	moderate increases in drainage network density due to roads (e.g., 5%)[8,9]	significant increases in drainage network density due to roads (e.g., 20-25%)[8,9]
Watershed Conditions:	Road Density & Location	<2 mi/mi^2 [11], no valley bottom roads	2-3 mi/mi^2, some valley bottom roads	>3 mi/mi^2, many valley bottom roads
	Disturbance History	<15% ECA (entire watershed) with no concentration of disturbance in unstable or potentially unstable areas, and/or refugia, and/or riparian area; and for NWFP area (except AMAs), 15% retention of LSOG in watershed[10]	<15% ECA (entire watershed) but disturbance concentrated in unstable or potentially unstable areas, and/or refugia, and/or riparian area; and for NWFP area (except AMAs), 15% retention of LSOG in watershed[10]	>15% ECA (entire watershed) and disturbance concentrated in unstable or potentially unstable areas, and/or refugia, and/or riparian area; does not meet NWFP standard for LSOG retention
	Riparian Reserves	the riparian reserve system provides adequate shade, large woody debris recruitment, and habitat protection and connectivity in all subwatersheds, and buffers or includes known refugia for sensitive aquatic species (>80% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/ composition >50%[12]	moderate loss of connectivity or function (shade, LWD recruitment, etc.) of riparian reserve system, or incomplete protection of habitats and refugia for sensitive aquatic species (70-80% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/composition 25-50% or better[12]	riparian reserve system is fragmented, poorly connected, or provides inadequate protection of habitats and refugia for sensitive aquatic species (<70% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/composition <25%[12]

1 Bjornn, T.C. and D.W. Reiser, 1991. Habitat Requirements of Salmonids in Streams. American Fisheries Society Special Publication 19:83-138. Meehan, W.R., ed.

2 Biological Opinion on Land and Resource Management Plans for the: Boise, Challis, Nez Perce, Payette, Salmon, Sawtooth, Umatilla, and Wallowa-Whitman National Forests. March 1, 1995.

3 Washington Timber/Fish Wildlife Cooperative Monitoring Evaluation and Research Committee, 1993. Watershed Analysis Manual (Version 2.0). Washington Department of Natural Resources.

4 Biological Opinion on Implementation of Interim Strategies for Managing Anadromous Fish-producing Watersheds in Eastern Oregon and Washington, Idaho, and Portions of California (PACFISH). National Marine Fisheries Service, Northwest Region, January 23, 1995.

5 A Federal Agency Guide for Pilot Watershed Analysis (Version 1.2), 1994.

6 USDA Forest Service, 1994. Section 7 Fish Habitat Monitoring Protocol for the Upper Columbia River Basin.

7 Frissell, C.A., Liss, W.J., and David Bayles, 1993. An Integrated Biophysical Strategy for Ecological Restoration of Large Watersheds. Proceedings from the Symposium on Changing Roles in Water Resources Management and Policy, June 27-30, 1993 (American Water Resources Association), p. 449-456.

8 Wemple, B.C., 1994. Hydrologic Integration of Forest Roads with Stream Networks in Two Basins, Western Cascades, Oregon. M.S. Thesis, Geosciences Department, Oregon State University.

9 e.g., see Elk River Watershed Analysis Report, 1995. Siskiyou National Forest, Oregon.

10 Northwest Forest Plan, 1994. Standards and Guidelines for Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl. USDA Forest Service and USDI Bureau of Land Management.

11 USDA Forest Service, 1993. Determining the Risk of Cumulative Watershed Effects Resulting from Multiple Activities.

12 Winward, A.H., 1989 Ecological Status of Vegetation as a base for Multiple Product Management. Abstracts 42nd annual meeting, Society for Range Management, Billings MT, Denver CO: Society For Range Management: p277.

Appendix A.8

Forestry Impacts on Freshwater Habitat of Anadromous Salmonids in the Pacific Northwest and Alaska—Requirements for Protection and Restoration

Appendix A.8

Murphy, M.L. 1995. Forestry impacts on freshwater habitat of anadromous salmonids in the Pacific Northwest and Alaska—Requirements for Protection and Restoration. U.S. Department of Commerce, NOAA Coastal Ocean Program, Decision Analysis Series No. 7. Silver Spring, Maryland.

This synthesis presents a science overview of the major forest management issues involved in the recovery of anadromous salmonids affected by timber harvest in the Pacific Northwest and Alaska. The key approaches to watershed management that are covered by this review are buffer zones, best management practices, cumulative impact prevention, and restoration.

The conclusion of the report with regard to buffer zones are that, to maintain or restore optimal habitat in fish-bearing streams, buffer zones should be at least as wide as the height of a mature tree, usually 30 – 40 m. Buffers should be managed to attain characteristics of mature native forest. Narrower buffers may not maintain adequate large woody debris (LWD) over the long term, and selected harvest within buffers further reduces LWD sources. No-harvest buffers are most appropriate along fish-bearing streams with mature forest, most common in Alaska and in National Forests. The report concludes that on private lands in other states, the number and size of leave trees should be increased where additional large conifers are available.

The author notes that many previously logged areas have degraded vegetation consisting mostly of hardwoods and brush and lacking large conifers. Restricting harvest would not necessarily improve habitat protection nor help restore riparian functions. The author states that active management of these riparian areas is needed to meet habitat requirements of fish. Selective harvest within these buffers could be used to improve riparian vegetation by thinning and conifer planting.

These above comments appear to be specific to areas where conifers are the native riparian vegetation. Areas where hardwoods are the native riparian vegetation do not necessarily need to be modified to a conifer forest.

The author notes that buffer zones are also needed along small non-fish streams that affect salmonid habitat. Except for federal lands under NFP and PACFISH, the usually minimal buffers on these streams on private lands means that their protection must rely on BMPs which do not always protect them from disturbance.

Appendix A.9

Rationale for a Managed Agricultural Buffer Zone in Skagit County

Appendix A.9
Natural Resource Consultants , Inc. 2000. Rational for a Managed Agricultural Buffer Zone in Skagit County, Draft. Prepared for the Skagit County Planning and Permit Center, Mount t Vernon, Washington, October 2000

Agricultural Impacts Information:

In response to “critical areas” designations under the state Growth Management Act and Endangered Species Act considerations, agricultural buffer zones are under review in Skagit County. This document provides technical justifications for specific buffer requirements.

The report states that agricultural practices may be a source of non-point pollutants reaching the Lower Skagit River through tributary streams, drainage ditches, and overflow lands. The key concern appears to be fecal coliform bacteria (from livestock waste); low dissolved oxygen, ammonia nitrogen, and silt deposits are noted as secondary problems.

The report states that a certain amount of the application of buffer zones has been based of best professional judgment and is most effective for specific ecological conditions. Also, much of the science and application of buffer zones has been applied to upland (forest) land conditions. In particular, the role of buffer zones in agricultural areas of the Pacific Northwest is very limited, thus yielding little empirical data from which to base decisions.

The report also details an adaptively managed agricultural riparian buffer for Skagit County. This includes buffer components related to large woody debris, temperature, and water quality, noting the relative effectiveness of various buffer options. The effectiveness levels are well qualified in some cases, noting that buffers can have limited impact depending on stream location and other conditions.

Buffer zones are prescribed as: Managed Riparian Buffer Zone (RBZ) first 25-ft from the ordinary high water mark; and Agricultural Management Zone next 50-ft. landward.

The RBZ would be a full buffer area, with self-sustaining vegetation and protection corridor; the AMZ would be limited agricultural uses and high-intensity management practices (limited crop types and pasture use periods).

Overall, the report does not “directly tie” the buffer zone recommendations to specific scientific observations; the emphasis is on general applicability. And the report does include considerable discussion about the variable level of effectiveness of specific buffer components, depending on several factors.

Appendix A.10

Review of the Scientific Foundations for the Forests and Fish Plan

Appendix A.10

CH2MHILL, Review of the Scientific Foundations of the Forests and Fish Plan. 2000. Prepared for the Washington Forest Protection Association.

This document is a review (Review) of the science upon which the Forests and Fish Plan (Plan) is based. The Plan is the collective term for the Forests and Fish Report (Report) and the Forests and Fish Emergency Rules. This Review contains two parts. The first section contains an overview providing the purpose of the review, the background and history of the Plan, a summary of the Plan, the legal context, a summary of the current habitat conditions and the science, and an overview of the adaptive management program. The second section provides seven in-depth discussions that review the habitat variables as they relate to each of the prescriptions outlined in the Report. Each functional discussion describes the ecological importance of each habitat variable, identifies the primary source areas and mechanisms for delivery to streams, describes the potential effects of forest practices on each input variable, and evaluates the possible effectiveness of the Plan's prescriptions in contributing to complex in- and near-stream habitats and/or desirable water quality.

The stated purpose of the Review is to identify the scientific foundations for the recommendations contained in the Report and to assess the effectiveness of the recommendations in meeting the goals set forth by the Washington Forest Practices Board and the authors of the Report.

The Plan was created to meet the following goals:

1. To provide compliance with the Endangered Species Act for aquatic and riparian-dependent species on non-federal forestlands.
2. To restore and maintain riparian habitat on non-federal forestlands to support a harvestable supply of fish.
3. To meet the requirements of the Clean Water Act for water quality on non-federal forestlands.
4. To keep the timber industry economically viable in the State of Washington.

In summary the Plan is a consensus recommendation for changes in forest practices statutes, regulations, and management systems to attain the stated goals. The Plan recommends increased resource protection through programmatic and prescriptive standards and guidelines. A primary focus of these new standards and guidelines is to manage riparian vegetation and sediment input to maintain or enhance stream habitats and water quality. The recommendations are intended to improve management in several key resource areas: large woody debris (LWD), heat energy, coarse sediment, fine sediment, hydrology, pesticides, and litterfall.

The Plan would broaden the list of fish covered by the rules and change the classification of streams to expand the area where protection is applied. Under the Plan, all fish would receive the same protection. The Plan proposes different riparian strategies for streams west of the Cascade crest (Westside) and streams east of the Cascade crest (Eastside) and for fish-habitat streams and non-fish-habitat streams.

Westside fish-habitat streams would be protected with buffers that extend up to site-potential tree height from the outer edge of the stream or channel migration zone. This distance is 90 to 200 feet, depending on the productivity of the land near the stream. Timber management within the buffers is progressively more restrictive in the zones closer to the stream. The riparian strategy consists of three zones. The "core zone" is the 50-foot no-harvest area closest to the stream. The "inner zone" is the area between 50 feet and 80 to 150 feet from the stream. Management in the inner zone would be prescribed to ensure that desired future riparian conditions grow and develop. The "outer zone" is the area beyond the inner zone. It would be managed to leave up to 20 trees per acre to protect special sites such as seeps, springs, or forested wetlands, or to provide permanent leave trees to support riparian protection. The Plan claims that management in the inner and outer zones would be controlled by rules to ensure that goals for riparian functions will be met, and that most protection is provided closest to the stream.

Westside non-fish-habitat streams are divided into two categories, perennial and seasonal streams. Perennial non-fish-habitat streams would receive a 50-foot-wide no-harvest buffer on each side for at least 50 percent of their length. The buffer would be placed at sensitive sites, such as perennial seeps, springs, unstable inner gorge slopes, alluvial fans and perennial stream intersections; and could border up to 100 percent of a reach's length. A 30-foot-wide equipment limitation zone on each side would border portions of perennial and all seasonal non-fish-habitat streams that do not receive 50-foot-wide no-harvest buffers.

Eastside fish-habitat streams would receive buffers that would extend to at least one site-potential tree height from the edge of the stream or channel migration zone, up to 130 feet. The no-harvest core zone would be 30 feet wide. The restricted inner zone would extend 75 or 100 feet from the core zone, depending on stream width. Where site-potential tree height is greater than the fixed inner zone width, up to 20 of the largest trees per acre would be left in the outer zone. Timber management in the inner zone would be controlled by maximum and minimum tree densities over a range of growing sites to address current and future riparian function and forest health.

Eastside non-fish-habitat streams would receive either a continuous managed 50-foot buffer where partial-cut management techniques are used, or a no-harvest, discontinuous buffer where clear-cut management techniques are used. The 30-foot equipment limitation zone would apply to portions of perennial streams without a leave-tree buffer and all-seasonal non-fish-habitat streams.

In addition to the riparian strategies, the Plan provides many other recommendations to improve forest practices permitting processes. These recommendations address: unstable slopes, forest roads, pesticide application, and wetland protection.

The Plan provides an overview of current habitat conditions on private forestlands. The Plan states that the most common factors influencing fish habitat are riparian harvest, stream cleaning, and road development. Grazing, water diversions, dams, and surface erosion are listed as more frequent factors in eastern Washington than in western Washington. Debris flows are listed as more common factors in western Washington.

The Review notes that the Plan was designed to adapt and change as new scientific learning becomes available. A cornerstone of the Plan is adaptive management which is the process of gathering and using scientific information to evaluate and improve management decisions. Monitoring is considered an important element of this adaptive management process and necessary to determine whether the aquatic resource goals, objectives, and targets are being achieved.

The following section summarizes the relevant watershed functions at the heart of the Plan that are contained within the Functional Discussions in Chapter 2. Chapter 2 contains seven Functional Discussions that review the habitat variables as they relate to each of the prescriptions of the Plan.

Functional Discussion 1: Large Woody Debris
This section discusses the ecological importance of LWD in streams, identifies the primary source areas and mechanisms for delivery to streams, describes the potential effects of riparian management on LWD, and evaluates the possible effectiveness of the Plan's prescriptions in contributing to complex in-and near-stream habitats and desirable water quality.

The Plan defines criteria and proposes forest practices standards to deliver LWD in riparian and aquatic areas. The Plan provides rationale for using LWD as a standard due to LWD's importance to the formation of fish habitat in streams and the influences on water quality and habitat quality in riparian areas. Further rationale given is the fact that forest practices may have an effect on the amount and timing of LWD in recruitment to streams from riparian areas and unstable hillslopes. The Plan states that forest practices need to ensure adequate supplies on LWD over the short and long terms.

Large woody debris is important because it influences channel morphology and fish habitat by:

- Forming pools where fish rear, feed, and seek refuge.
- Storing sediment to improve water quality and provide spawning areas.
- Scouring the streambed and banks to diversify water depths and gradients, and to deliver nourishment and shade.
- Producing a diverse channel morphology that contributes to habitat and hydraulic complexity.

The Plan concludes that natural wood recruitment to Westside streams is governed by a relatively small set of landscape disturbance factors, which includes: bank erosion, windthrow, tree mortality, and mass wasting. LWD recruitment mechanisms for trees to the Eastside stream channels are unique. Stream capture and deadfall are the most common recruitment mechanisms; and mass wasting, windthrow, and transport from upstream are the least common mechanisms cited by watershed analyses.

The Plan identifies three LWD source areas:

1. <u>Near-stream riparian stands</u>: areas directly adjacent to the stream where coarse wood is delivered directly to a given reach through mortality, windthrow, and streambank erosion processes;
2. <u>Upstream riparian stands</u>: near-stream riparian sources that are upstream of a given reach (flotation during flood water or debris torrents transports the wood to its current location after initially falling into an upstream reach from an adjacent stand); and
3. <u>Upslope stands</u>: zero-order channels, hollows, or hillslopes (landslides and landslide-debris torrent combinations that transport large wood to a given reach).

The Review states that in a riparian zone, the width of the source area for delivery of wood of any size approaches a distance that is approximately equal to the average height of trees in the riparian stand. The source area for functional LWD is narrower than the average tree height because the top 10 to 15 feet (3 to 5 m) of trees are branches and leaders less than 4 inches (10 cm) in diameter (minimum functional wood size). The width of the source area varies by site, and is a function of site productivity and stand age. Research studies have reported that most of the potential LWD supply comes from widths of 31 to 131 feet (9 to 40 m), depending on location and stand type.

The contribution of LWD from riparian trees is greatest for trees near the channel and decreases with distance from the stream because the probability of a tree intersecting a stream decreases with distance away from channel (Van Sickle and Gregory 1990). Hence, the potential for recruitable trees decreases with increasing distance from the channel. In addition, bank erosion causes trees to preferentially fall toward the stream so that the trees closest to stream bank have the highest probability of recruitment. This is evident in the LWD source-distance curves. The source-distance curves of McDade et al. (1990) represent LWD delivery to steep, small channels, which are almost always constrained by boulders and bedrock. They probably over-represent the source-distance relationship for LWD delivery along alluvial channels, which are more likely to be fish-habitat streams. Therefore, using the McDade source-distance curves probably results in overestimates of the relative contribution from trees standing farther from lower gradient, alluvial, fish-habitat channels.

The following table appears in the Review:

Width of the Source Area Providing 95 Percent of the LWD Supply from Old-Growth and Mature Stands

Location (Stand Type)	Width of the Source Area Providing 95% of the Potential LWD Supply feet (meters)	Reference
Southeastern Alaska (old growth)	31 ft (9 m)	Martin et al. 1998
Southeastern Alaska (old growth)	66 (20)	Murphy and Koski 1989
Eastern Washington (mature)	91 (28)	Light and Cupp 1999
Western Cascades, Washington (mature)	49 (15)	McKinley 1997
Western Cascades, Washington and Oregon (mature)	108 (33)	McDade et al. 1990
Western Cascades, Washington and Oregon (old-growth)	131 (40)	McDade et al. 1990

Regarding the influence of LWD on fish habitat the review states that few studies have provided empirical data that can be used to determine desirable and acceptable amounts of LWD. Studies have shown that the effectiveness of LWD for forming pools declines with an increase in LWD load, and the relationship varies by geomorphic channel type. Additional studies have concluded that pool frequency increases as the number of pieces of LWD increase.

The Plan addresses LWD by using the desired future condition (DFC) of forests and riparian areas as a planning concept for forest management. The DFC sets a vision for a development trajectory and a range of future conditions. For Westside riparian zones the Plan identifies mature conifer stands as a target for a DFC. The Westside DFC was developed by recognizing that large trees are needed close to streams to supply functional wood and that the size of trees in the current managed forests is limited by age. On the Eastside, the DFC concept is implicit in the management goals for riparian forest stands. Eastside riparian vegetation reflects the growing conditions and habitats created by climate and associated disturbance regimes. The goal of the Eastside riparian strategy is to create healthier riparian forest conditions that are more sustainable and resistant to catastrophic fires, and disease and insect infestations.

The Plan contains prescriptions that aim to maintain a long-term supply of LWD by addressing the major source areas and input processes. The LWD management measures include:

- Riparian Management Zones (RMZs) and Sensitive RMZs
- Management of Potentially Unstable Slopes and Landforms
- Forest Road Management
- Wetland Protection

The Review concludes that riparian forests that maintain growth trajectories toward DFCs that are similar to mature forests are presumed to provide adequate and functional levels of LWD to streams. The Review further concludes that the Plan's proposals for silvicultural options for management of LWD protects LWD sources where they are most needed and at locations where LWD can be most effective, particularly near aquatic resources and along fish-habitat streams.

The Review states that to consider the adequacy of the *Forests and Fish* plan, the following critical question needs to be addressed:
Are the proposed forest practices rules in the Forests and Fish plan adequate for providing sufficient amounts of LWD to streams to attain water quality standards, and support fish and other aquatic and riparian life?

The authors of the review attempt to assess the effectiveness of the prescriptions for supplying LWD by comparing the proposed RMZ widths to the widths of the potential LWD source areas. It is important to note that proposed buffer widths along fish-habitat streams are based on SPTH, depending on forest Site Class. Therefore, on the Westside, RMZ widths range from 90 to 200 feet (27 to 61 m) for Site Classes V through I, respectively. Similarly, on the Eastside, RMZ widths range from 60 to 130 feet (18 to 40 m) for Site Classes V through I, respectively. Because the width of the source area varies with site productivity, the actual source-distance data that were gathered in terms of horizontal distance from channels were normalized, for purposes of this analysis, to a representative site-potential tree height (SPTH) for the Westside and Eastside. SPTHs of 200 and 130 were used to normalize the Westside and Eastside data, respectively. For western Washington, the old growth data from McDade and others (1990) were adjusted to SPTHs for Site Classes I to IV. The old-growth data from McDade and others were used instead of their mature-stand data to be a more conservative estimate of the potential LWD supply. [Note: the data from McDade and others were derived from steep, confined channels, and that they likely over-estimated the contribution of trees farther from the channel.] For eastern Washington, the data from Light and Cupp (1999) were adjusted to SPTHs for Site Classes I to IV. Site Class V was not included because it represents a very small percentage of forest stands in Washington.

In this evaluation, the width of each prescribed riparian management zone (i.e., core, inner, outer) was converted to its equivalent SPTH by Site Class, and the corresponding potential LWD supply (i.e., cumulative percent of LWD pieces) was determined from either McDade and others' or Light and Cupp's source-distance curves, depending on region.

This defines the proportion of the potential LWD supply that would be affected by the prescription for each zone in the RMZs. A conservative assumption for source distance is made because trees at increasing distances from channels have a decreasing probability of contributing functional LWD to streams—their tops are too small to contribute functional wood due to stem taper.

The amount of in-stream LWD produced by the *Forests and Fish* plan's prescriptions is a function of the riparian source area width and riparian stand characteristics. These characteristics include tree species, size, and density); tree growth and mortality rates; tree recruitment processes; tree fall direction; and wood loss over time. Riparian protection prescriptions that allow some management in riparian zones can have an effect on all of these processes perhaps with the exception of wood loss. The minimum effectiveness of the prescriptions is the product of source area width and the percent of the timber stand retained within source areas, based on the silvicultural prescriptions in the *Forests and Fish* plan. The results of the prescription effectiveness evaluation are presented in Tables 2.1-8 and 2.1-9.

The relative proportion of the SPTH that would be in the core zone (i.e., unharvested) is a progressively larger portion of the SPTH distance for each lower Site Class. For example, in Site Class I for the Westside, the 50-foot-wide (15-meter-wide) core zone represents 25 percent of SPTH, but 62 percent of the potential LWD supply. However, in Site Class III, the 50-foot-wide core zone represents 36 percent of SPTH, but 73 percent of the potential LWD supply (Table 2.1-8). It should be noted that the average site productivity on western Washington forestlands is Site Class III. For purposes of this analysis, prescriptions that maintain all existing timber (no harvest option), or improve stand conditions to achieve a prescribed DFC, are considered 100 percent effective.

The Review's analysis found that the general effects of the prescriptions for fish-habitat streams are similar for both the Westside and Eastside. In both regions, the intensity of harvest and RMZ management increases with distance from the stream, and the proportion of the LWD source area affected decreases with distance from the stream. On the Westside, for example, zero harvest in the core zone would maintain an unmanaged stand supplying 62 to 79 percent of the potential LWD. Limited-harvest options within the inner zone would supply 14 to 34 percent of the potential LWD. The relatively greater tree harvest in the outer zone would affect only 5 percent or less of the potential LWD supply.

The Review concluded that indications are that the proposed prescriptions would contribute less than the maximum LWD recruitment potential, but an amount similar to natural circumstances, and likely to be effective for forming fish and riparian habitat. In addition, the proposed new water-typing system would extend buffer zone protection over a larger portion of the stream network than the old rules because it would protect all fish habitat, not just fish habitat that is currently occupied by fish.

A few more details of the Review's analysis are described below:
Variations of harvest options within the Westside inner zone would affect the percentage of trees retained and the long-term potential of this zone to supply LWD. The *Forests and Fish* plan would make both the thinning and clearcut options for the inner zone dependent on meeting the DFC. Harvest would not occur in the inner zone unless it could be demonstrated that sufficient trees would be retained in the combined core and inner zones to meet the functional targets of DFC. The only trees that could be removed are ones that would be surplus to what is needed to grow to DFC. Thinning would be further constrained by the stipulation that only the smallest trees be removed, that the proportion of conifer not be reduced from the pre-harvest level and that a minimum of 57 trees per acre remain in the zone.

Under the inner-zone Westside thinning option and Eastside partial-cut, growth rates of residual trees would be greater over time and the future stand would be more likely to contribute large pieces of wood. By leaving the largest conifer trees and reducing competition, thinning accelerates diameter growth of the leave trees, making large wood available for recruitment to streams sooner than would otherwise be the case. Where trees are thinned (Option 1) or where a partial cutting is applied (Eastside only), the stand would maintain or improve LWD supply because thinning and partial cutting are designed to increase the growth rate of leave trees, which would become large enough to contribute LWD from the inner zone. Therefore, thinned and partially cut inner zone stands, combined with unmanaged stands in the core zone, could supply at least 91 to 100 percent (Eastside) and 95 percent (Westside) of the potential LWD, depending on stream size and region.

If, on the Westside, the clearcut harvest (Option 2) is applied to the inner zone, the sourcearea in the inner zone would be reduced. The minimum no-harvest width of the core and inner zones (combined) under Option 2 would be no less than “floors” of 80 feet for small streams and 100 feet for large streams; this unmanaged stand would supply 78 to 96 percent of the potential LWD. Reduction in source area from the full core/inner zone widths toward the floors would be limited by the need to retain sufficient trees to achieve the DFC targets.

In other words, the inner zone can be made more narrow only if sufficient trees to meet functional targets are retained in the riparian zone. Under the clearcut option, individual tree growth rates would be unchanged, but more trees would hit the stream due to proximity, and the sizes of wood would be greater because a lower proportion of trees would consist of tops. Timber harvest in the outer zone of fish-habitat streams would have a limited effect on LWD supply because only a very small portion of the LWD is derived from this area and a higher proportion of trees would consist of tops. Tree clumping around sensitive areas and minimum tree retention requirements (i.e., 10 to 20 trees per acre) in this zone would maintain some of the LWD supply.

Unlike the Eastside prescriptions in the Forests and Fish plan, riparian management strategies that promote unmanaged riparian forests, combined with fire suppression, may result in unintended consequences related to the local natural disturbance regime. For example, riparian reserve areas where management is excluded can become corridors for severe wildfire (Segura and Snook 1992; Agee 1998). This is particularly true on the Eastside where fire suppression can increase the rate and magnitude of disease and insect outbreak. The inability to manage within portions of the RMZ along fish-habitat streams may increase the risk of fire and its associated impacts to fish habitat. Active management prescriptions of the Forests and Fish plan provide assurances that catastrophic and unnatural stand replacement fires would be minimized.

Results of the review are summarized for the east and west sides in the Tables below:

Proportion of Potential LWD Supply to Streams in Western Washington under the *Forests and Fish* Plan [a]

Zone	Proportion of Potential LWD Supply (%) Site Class [b, c] I	II	III	IV	Percent of Timber Stand Retained Within Potential LWD Source Area [d]
Fish-Habitat Streams (Type S and F Waters)					
Core Zone (50-ft)	62	68	73	79	100% (No harvest)
Inner Zone					
Small Streams					
Option 1 (Thinning)	33	27	22	16	100% (Over the long term as stand reaches DFC target)
Option 2 (Clearcut)	14-33	13-27	8-22	n/a	100% (No harvest in unmanaged area)
Large Streams					
Option 1 (Thinning)	34	28	23	17	100% (Over the long term as stand reaches DFC target)
Option 2 (Clearcut)	21-34	25-28	n/a	n/a	100% (No harvest in unmanaged area)
Total RMZ (Small and Large Streams Combined)					
Option 1 (Thinning)	95	95	95	95	
Option 2 (Clearcut)	78-96	81-96	81-96	n/a	
Perennial Non-Fish-Habitat Streams (Type N Waters)					
First 300-500' Above Fish-Habitat Streams	62	68	73	79	100% (No harvest)
Full Length	31-62	34-68	36-73	40-79	6-100% (No harvest over at least 50% of length)

[a] Based on old-growth data from McDade et al. (1990) (See Figure 2.1-6).
[b] Site Class V was left out because it represents a very small percent of forest stands in Washington.
[c] Because the Westside outer zone represents 5 percent or less of the recruitment area and prescriptions have a limited potential to supply LWD, it is not included in the total.
[d] Excludes timber retention along sensitive sites and potentially unstable slopes and landforms.

Proportion of Potential LWD Supply to Streams in Eastern Washington under the *Forests and Fish* Plan [a]

Zone	Proportion of Potential LWD Supply (%)				Percent of Timber Stand Retained Within Potential LWD Source Area[d]
	Site Class [b, c]				
	I	II	III	IV	
Fish-Habitat Streams (Type S and F Waters)					
Core Zone (30-ft)	66	70	76	82	100% (No harvest)
Inner Zone					
Small Streams					
Ponderosa Pine & Mixed Conifer	25	24	21	18	100% (Over the long term as stand reaches DFC target)
High Elevation Option 1 (Thinning)[d]	28	24	18	12	100% (Over the long term as stand reaches DFC target)
Large Streams					
Ponderosa Pine & Mixed Conifer	30	26	24	18	100% (Over the long term as stand reaches DFC target)
High Elevation Option 1 (Thinning)[e]	30	28	24	18	100% (Over the long term as stand reaches DFC target)
Bull Trout Habitat	25	24	21	18	100% (No harvest)
Total RMZ					
All Streams & Habitat Types Combined	91-96	94-98	94-100	94-100	
Non-Fish-Habitat Streams (Type N Waters)					
Partial-Cut Units	81	85	91	95	100% (Over the long term as stand reaches DFC target)
Clearcut Units	81	85	91	95	0-100% (No harvest over at least 70% of length; minimum BA and density are designed to meet DFC)

[a] Based on source-distance data from Light and Cupp (1999) (See Figure 2.1-6).
[b] Site Class V was left out because it represents a very small percent of forest stands in Washington.
[c] Because the Eastside outer zone represents 5 percent or less of the recruitment area and prescriptions have a limited recruitment potential, it is not included in the total..
[d] The clearcut option does not apply to Eastside, high-elevation forests.
[e] Excludes timber retention along sensitive sites and potentially unstable slopes and landforms.

Functional Discussion 2: Heat Energy

CH2M HILL reviewed the scientific foundations effectiveness of temperature amelioration by shading from forest buffers. After summarizing various physical processes that impact stream heating, the review notes the physical conditions of upper watershed tributaries in forest have greater ground water influx that provides a substantial proportion of total stream inflow. Groundwater of course is generally uniformly between 40-50 C in cascade mountain environments. The review also describes the diminishing impact of groundwater influx has on cooling as the stream flow grows larger and collects more and more surface water at the lower altitude reaches and in the lower order streams. The review suggests that as the total volumetric flow rate of a stream increases, the total surface flow tends to grow larger faster in proportion to the rate of ground water influx.

This effect tends to afford larger streams less cooling effect from ground water influx than that expected for smaller streams toward the head of the watershed.

The review describes other factors that come into play as the stream widths increase with decreases in altitude. In the upper reaches of the watershed, riparian shading tends to more effectively cover the entire stream. As the streams coalesce to the lower altitude reaches, the streams become wider, so riparian canopies contiguous to the wider streams automatically provide less shade for a given canopy height due to the greater mean distance from the stream banks to the stream centerlines. This tends to effectively shift the mean distance to the start of the buffer zone away from the stream centerline. Thus, shade function becomes a decreasingly effective treatment in larger order (wider and deeper) streams. Since most agricultural streams are in valley bottoms, not mountain tops, there are probably more higher order (larger) streams than in the upland forests. Shade has less of a total impact on reducing temperature in larger order streams because the mass of larger order streams is larger and thus more resistant to heating and cooling. Thus the general importance of shading is probably a less important factor in influencing temperature in agricultural ecosystems than in forest ecosystems.

Many local factors influence the actual stream temperature response, so it is difficult to quantify average impacts or effects. A wide range of variability appeared in the results obtained for canopy cover effects as presented in the review. In this same section, (Effects of Proposed Rules on Shade) a discussion of potential shade effectiveness was addressed. One group of cited studies came to agreement that most of the potential shade effectiveness comes from the buffer region within 75 feet of the stream bank, they differed considerably on the exact value for an appropriate optimal buffer zone width. Effective buffer zone widths ranged from 39 to 98 feet from the stream bank. No information describing the total stream width or total canopy height was supplied in the review to supplement the reported findings.

The review then describes additional studies done to verify the abilities of the various geographically developed shade rules to adhere to target temperature criteria. For that investigation, the effective shade was expressed in terms of the buffer zone width as a percentage function of the theoretical site potential tree height. In this case, a site potential tree height of 200 feet was used, and a quantity referred to as the Angular Canopy Density (ACD) was used to define the effective shade potential of a buffer zone. The results of two different studies were compared in which it was found that considerable discrepancies existed for buffer zone widths inside about 50% of the (200 ft) theoretical site potential tree height, but that the results tended to converge to close agreement above about 65% of the site potential tree height.

A comparison of target vs. actual canopy closure was then compared to target vs. actual temperature standards. The results of this study tended to show a strong inverse relationship between canopy density and temperature standard attainment. However, it did not describe whether the observation sites were compared under otherwise uniform conditions of stream width, depth, and altitude to describe whether the stream reaches compared here were otherwise relatively equivalent. The concern is that the results could easily be skewed by the fact that narrower streams at higher altitudes will be more likely to attain their targets and would be covered more effectively by increased canopy density than would the wider streams at lower altitudes.

In terms of the transferability and applicability of this type of an approach for use in agricultural systems, the same theory and the same potential benefits are certainly legitimate. There is obvious applicability to irrigation canals, and to smaller rivers and waterways to varying extent would be worthy of consideration. One issue would be the existing local conditions that would play a larger role in the approach than for higher altitude narrower streams where a reasonably dimensioned buffer zone would impart significant reductions in radiation loading. On very wide rivers, buffer zones could delay the onset of direct incident solar radiation, but inevitably the sun would reach a high enough solar angle to overtop the buffer zone. The relative orientation of the river comes into play as well. Rivers running directly north or south would tend to be subjected to direct midday sunlight even with a dense, tall riparian buffer zone in place. Rivers running east to west would benefit more from a buffer zone situated on the south bank than from one on the north bank since the sun is always south of the zenith in the northern hemisphere for any latitude north of 21° north of the equator. Thus the idea that a uniform buffer width on either side of a stream imparts the same benefits is completely false when it comes to shade benefits.

It should be pointed out that some apparent rules of thumb described in the CH2M HILL review are not necessarily always true. For example, the report tends to suggest that shallow streams always tend to heat more rapidly than deeper streams. This is only true in cases where the surface area to volume ratio of the shallow stream is greater than that of the deeper stream. The important characteristic to judge the tendency of a stream to respond aggressively to energy inputs is the surface area to volume ratio; not the depth.

Functional Discussion 3: Coarse Sediment

This section discusses the ecological importance of coarse sediment delivery to streams, the primary sources and mechanisms for delivery, and the potential effects of forest practices on potentially unstable slopes and landforms, and evaluates the possible effectiveness of the Plan's proposed programmatic and prescriptive rule changes and implementation commitments.

The Review concludes that the Plan contains a clear and defensible list of the diagnostic landforms of Washington that are potentially unstable, and an administrative process for identifying, reviewing, and regulating forest practices on potentially unstable slopes. It targets the highest-risk areas (e.g., road-related mass wasting) first, and would accelerate problem-reduction activities. The Review further concludes that the Plan contains appropriate ingredients for significantly reducing the effects of forest practices on landsliding and the introduction of excessive coarse sediments to public resources.

The Review summarizes the coarse sediment issue by concluding that coarse sediment delivery to streams may have positive and negative effects on aquatic habitats. Mass wasting (landsliding) in forested drainage basins is given as the principal, natural mechanism by which coarse sediment enters stream channels from hillslopes. Forest practices are also mentioned as having a possible effect on mass wasting by reducing root strength, increasing soil moisture, and altering slope stability characteristics during road construction and maintenance.

The stated resource objective of the Plan is "to prevent the delivery of excessive sediment to streams by protecting unstable slopes, and preventing the routing of sediment to streams." The Plan addresses this objective by containing programmatic and prescriptive rule changes to address forest practices on potentially unstable slopes and landforms.

The Review begins this section by discussing the immediate short-term effects of mass wasting on channel habitat. These effects are:

- The capacity of the stream to transport material downstream is overwhelmed by the large influx of sediment, wood and other organic material.
- The increased sediment deposition aggrades channels.
- The average grain size of the channel bed decreases.
- Riparian vegetation is damaged or removed.

The potential negative impacts from mass wasting on aquatic habitats include direct fish kills and habitat loss by burial, increase in the potential for dam-break floods, and influx of excess fine sediment.

The Plan identifies erosion processes and input sources that cause coarse sediment to enter stream channels including mass wasting, bank erosion, sheet wash, and gullying.

The potential effects of forest practices can contribute to slope instability and fall into the following categories:

- Failure of road fills or sidecast material.
- Reduction in rooting strength.
- Increase in soil moisture due to increased snow accumulation and subsequent melt and/or loss of evapotranspiration potential.
- Alteration of drainage patterns due to road construction or road maintenance.
- Alteration of near-stream channel riparian vegetation.

The most on-point discussion to riparian buffers regarding coarse sediment in the Review involves vegetation removal. The Review states that vegetation removal increases the amount of precipitation reaching the ground and decreases the amount of water that is removed from the ground by vegetative transpiration.

Numerous studies of landslide incidence have pointed to poorly planned, designed and maintained legacy roads that were constructed prior to modern forest practice rules as the greatest forestry-related contributor increasing the rate of landslides in managed forests (NCASI 1985; Robison et al. 1999; Pyles et al. 1998). Such roads can increase soil saturation enough to trigger shallow landslides. It is well demonstrated that the concentration of road drainage onto steep, unstable slopes can lead to increased landslide activity (Megahan1972). While this discussion is presented in the context of forest practices, it can also be relevant to agriculture in situations where roads have been constructed for agricultural purposes, particularly in situations where slopes are moderate to steep.

The authors describe the effect of forestry harvest on slope stability. This discussion is specific to forestry and it may be less relevant to agriculture because crops are not usually grown in areas with steep slopes and shallow soils. In addition, agriculture replaces trees with other types of vegetation, which may or may not have similar root strength as the native vegetation. Root strength is important in shallow soils on steep slopes where studies that have documented an increase in shallow landslides following timber harvest (Burroughs and Thomas 1977; Ziemer 1981). The effect is similar to the effect of stand replacement fires on landsliding and continues until new vegetation attains approximately 10 to 30 years of age (Robison et al. 1999; Benda et al. 1998).

To address the general concern about removing riparian trees that could stop debris flows the Plan would mitigate potential negative effects through two mechanisms. First, it would protect the bedrock hollow initiation points and a substantial portion of the downstream first- and second-order channel network that contains trees to stop debris flows before they could build too much momentum. Second, it would provide substantial protection for riparian areas and some unstable slope areas along higher-order confined channels that may experience dam-break floods.

The Review notes that a theoretical basis exists for leaving trees to reduce landslide potential. The Review then notes that there has been very limited field application of leave areas and only one study has evaluated their effectiveness. This study was conducted in the Suislaw National Forest in Oregon and concluded that leave areas had either no effect or led to an increased rate of failures due to tree blowdown (Martin 1997).

Functional Discussion 4: Fine Sediment

This section discusses the ecological importance of fine sediment delivery to streams, the primary sources and mechanisms for delivery, the potential effects of forest practices on roads and drainage systems, and evaluates the possible effectiveness of the Plan's proposed programmatic and prescriptive rule changes and implementation commitments.

The Review concludes that the Plan contains a clear and defensible administrative process for identifying, reviewing, and regulating forest practices that may contribute to fine sediment delivery. The Plan's prescriptions address the management practices and landscape areas with the highest potential to deliver fine sediments to streams. The Review further concludes that the recommended management prescriptions are stricter than the old rules, and their potential effectiveness is supported by scientific research.

The stated resource objective in the Plan is to “prevent the delivery of excessive sediment to streams by protecting stream bank integrity, providing vegetative filtering, and preventing the routing of sediment to streams.” The Plan provides management prescriptions to prevent or minimize the impact of forest practices on surface erosion processes. The major commitments to reducing sediment delivery to streams are:

- Disconnecting road drainage systems from streams.
- Reducing water and sediment delivery from existing stream-adjacent roads.
- Higher construction standards for new roads.
- 30- or 50-foot-wide no-entry core zones with additional tree retention out to a distance equal to one site-potential tree height for fish-habitat streams.
- 30-foot-wide equipment limitation zones with leave-tree requirements for non-fish-habitat perennial streams.
- Riparian management zones on non-fish-habitat perennial streams avoid ground disturbance at seeps, springs, and other sensitive areas.

The Plan provides an overview of studies that have shown that increases in stream sedimentation can lead to impacts on aquatic habitat and water quality. Specifically, high fine sediment levels can reduce salmonid survival-to-emergence ratios by entrapping eggs within the streambed and limiting inter-gravel flow of oxygenated water. Also, fine sediment can fill the interstitial spaces between gravels that juvenile salmonids, benthic invertebrates, and amphibians use for cover and reduce growth and survival. Additionally, increases in fine sediment levels can impact biota such as benthic invertebrates that are a significant food source for adult salmonids, and the filling of pools by fine sediment can reduce rearing habitat for salmonids.

Fine sediment can be generated from on-site processes, such as physical and chemical weathering of geological features, loss of vegetation or organic duff, and streambank erosion. Fine sediment can be transported off-site by wind or surface water run-off.

The Review concludes that forest practices that remove or disturb the protective duff layer on the forest floor, compact the soil, or increase the slope angle have the greatest potential to increase soil erosion rates. Additionally, activities that increase or concentrate the flow of water over soil can increase the amount of erosion and the likelihood of delivering sediment to streams. Specific activities that can increase soil disturbance and surface erosion include road construction, road maintenance, ground and cable yarding, and site preparation.

The Review states that roads represent the greatest potential source of fine sediment production from forest practices. Importantly, the Review concludes that soil compaction and displacement in riparian areas can change soil physical properties and increase delivery of sediment to streams. Soil compaction from ground-based logging or roads can reduce infiltration rates and impede the ability of soils to store water.

Rashin et al. (1999) found that streamside buffers are generally effective at preventing sediment delivery, but that yarding timber within 30 feet of streams without buffers often causes soil disturbance, bank erosion, and sediment delivery to streams.

The Plan includes numerous prescriptions to address the potential for delivery of fine sediment from roads and timberlands. It addresses surface erosion within riparian harvest units by providing 30- or 50-foot-wide no-harvest core zones along fish-habitat streams, and 30-foot-wide equipment limitation zones along all non-fish-habitat streams. The new rules would make it more difficult to build roads in riparian areas or adjacent riparian forest. The Review states that research suggests that, on average, leave-tree widths of 30 feet or more should be effective at filtering out sediment from adjacent timber harvest activities (Brake et al. 1997; Rashin et al. 1999). The Review concludes that the 30- or 50-foot-wide no-harvest zones along fish-habitat streams, and equipment limitation zones on non-fish-habitat streams should prevent soil compaction and bank disturbance in the area with the greatest potential for sediment delivery. The Review further concludes that in most cases, the leave-tree requirements for fish-habitat streams would provide buffers that are wider than the maximum sediment delivery distance reported for older roads (Brake et al. 1997).

The Review further concludes that forest practices rules are proven to be effective when properly implemented. Therefore, the fine sediment problems that have been identified in Washington can be solved through proper application of well-understood forestry best management practices (BMPs).

Functional Discussion 5: Hydrology

This section discusses the ecological roles of forest hydrology, identifies the primary hydrologic processes and water input sources, describes the potential effects of forest and road management on hydrologic regimes, and evaluates the possible effectiveness of the Plan's prescriptions in reducing the effect of forest practices on hydrologic processes.

The Plan proposes forest practices standards to help maintain the hydrological regimes of private forestlands. The resource objective for hydrology stated in the Plan is to "maintain surface and groundwater hydrologic regimes (magnitude, frequency, timing, and routing of stream flows) by disconnecting road drainage from the stream network, preventing increases in peak flows causing scour, and maintaining the hydrologic continuity of wetlands." This objective is important because the hydrologic regimes influence water and habitat quality in watercourses and riparian areas and are important to the formation of fish habitat in streams.

The Review discusses the scientific principles of hydrology. In this discussion the Review concludes that by virtue of their location in watersheds and proximity to watercourses, riparian forests may influence the local hydrologic condition and bank stability. Vegetation primarily influences flow through interception (collection of rain and snow by the canopy) and evapotranspiration. Additionally, historical fire suppression and the build up of abnormal quantities of biomass in riparian areas have altered forest hydrology and its associated ecological processes to create conditions outside the natural ranges of variability, particularly in many Eastside forest locations.

The Review discusses how forest practices have affected hydrologic processes and concludes that forest practices can affect hydrologic processes primarily through the alteration of vegetation and soil properties. Additionally, tree removal can temporarily reduce interception and evapotranspiration, increase soil water storage, and affect the quality and timing of streamflows.

The Plan addresses hydrology by providing for changes in the application of rules to reduce the influence of forest practices on hydrologic regimes. The pertinent change is that riparian protection is to be extended to include entire channel migration zones associated with fish-habitat streams. This change is to ensure that trees are retained within the area of active channel movement within valleys. The extended protection is expected to protect the zones of shallow subsurface flow beneath and adjacent to migrating streams.

The Plan also includes additional prescriptive changes to further reduce the effects of forest practices on hydrologic processes. The pertinent changes are to establish Riparian Management Zones (RMZs) and Sensitive Site RMZs which have tree retention provisions for priority areas and aquatic features on perennial, non-fish-habitat waters and equipment limitation zones.

The Review concludes that the Plan provides additional provisions that will further reduce the effect of forest practices on hydrologic processes in three general areas: roads, wetlands, and riparian zones. The changes are expected to reduce soil disturbance and compaction at areas with significant shallow subsurface flow and reduce the amount of concentrated road drainage flowing directly to streams.

The Review further concludes that the riparian prescriptions that address hydrologic processes are expected to provide a higher level of hydrologic protections. Sensitive Site RMZs emphasize tree retention around seeps, springs, and forested wetlands, which may be hydrologically sensitive. Channel migration zones are recognized as part of the channel, and therefore are included within the no-harvest portion of the RMZ. These measures are expected to protect shallow subsurface flows beneath and adjacent to these streams, which are important for supporting a variety of aquatic organisms.

Functional Discussion 6: Pesticides

This section discusses the role of herbicides in managing forests, describes the potential effects of herbicide application on fish habitat and water quality, and evaluates the effectiveness of the Plan's BMPs. The Plan proposes BMPs designed to eliminate the direct entry of herbicides to waters and wetlands, to protect riparian vegetation, and to minimize off-target drift to water and vegetation in riparian zones.

The Review claims that herbicide research confirms that the RMZs in the Plan would eliminate the direct entry of herbicides to water and wetlands, and protect riparian vegetation and that the Plan's prescriptions substantially increase the confidence that herbicides can be used without adverse environmental effects.

Concern about herbicide use generally focuses on its potential toxicity to unintended targets. For example, sublethal effects of some herbicides on salmonids include reduced growth, decreased reproductive success, altered behavior, and reduced resistance to stress.

Payne and others (1989) found that a buffer width of 82 feet (25 m) around water bodies is adequate to protect salmon, rainbow trout, and aquatic invertebrates from significant direct effects resulting from application of certain technologies.

The discussion and conclusions in this section may not be applicable to agricultural buffers due to the fact that herbicides are commonly undetectable in managed forest environments. For example, the USGS (1996) reported, "Of the 25 most frequently detected pesticides, 3 were found primarily at urban sites, 6 were found primarily at agricultural sites, and 7 were found at all types of sites except forested sites." The Review discusses that one reason herbicides are undetectable on forestland may be that the frequency of herbicide application on forestland, compared with agricultural and urban land, is relatively low.

The Plan recommends a very low risk approach under favorable wind conditions of 50-foot-wide (15 m) off-sets on non-fish-habitat streams with open water, and 60- to 150-foot-wide (18 to 46) off-sets, depending on inner riparian zone width. Under unfavorable wind conditions when potential drift is a concern, the Plan's low risk approach to stream protection would invoke 145- to 325-foot-wide (44 to 99 m) buffers, depending on application height and nozzle type.

The Review concludes that the Plan's goals of eliminating direct entry of herbicides to waters and wetlands, minimizing off-target drift, and protecting riparian vegetation in RMZs should be accomplished under these off-set widths with a large margin of safety.

Functional Discussion 7: Litterfall

This section discusses the importance of organic inputs from forestlands, describes the effects of forest practices on organic litter, and evaluates the effectiveness of the Plan's prescriptions to restore and maintain adequate levels of organic inputs to streams.

The Plan defines ecological criteria and proposes forest practices standards to deliver organic litter to riparian and aquatic areas. Organic litter inputs to streams are important food and energy sources for a variety of organisms that, in turn, provide food and energy for fish and other aquatic organisms. Forest practices have the potential to affect organic litter generation and transport from riparian forests to aquatic areas.

The Review discusses the effectiveness of organic litter sources in stream ecology. This effectiveness is based on the interaction of vegetation with the stream. Stream size influences the role of litterfall and, generally, a relatively higher proportion of litter function is provided by near-stream vegetation as stream size decreases.

In an overview of the science the Review discusses deciduous riparian forests verses coniferous riparian forests. In deciduous riparian forests, approximately 80 percent of the organic material input to streams is derived from leaf litter. In coniferous riparian forests, needles contribute a major portion of the terrestrial input to streams, and fallen cones or wood may account for 40 to 50 percent of the total terrestrial litter input.

The Review assumes that most litterfall to streams is generated close to the channel. This assumption is based upon the Forest Ecosystem Management Assessment Team (FEMAT) litterfall effectiveness curve that suggests that approximately 90 percent of the litterfall to streams originates within half a site-potential tree height from the stream (FEMAT 1993). Indirect evidence of litterfall effectiveness is suggested by benthic invertebrate communities. Studies in streams with managed riparian buffer zones at least 100 feet (30 m) wide had benthic communities that were indistinguishable from streams flowing through logged watersheds (Erman et al. 1997; Belt et al. 1992). However, maintenance of overhanging trees and shrubs within just 10 feet (3 m) of the bank has been found to maintain the sources of most litterfall (Newton et al. 1996). The Review concludes that forest practices that affect litterfall processes have the potential to modify the vegetation-stream relationship, including nutrient and energy sources to streams.

The Plan's forest practices measures are essentially the same as the ones intended to maintain and enhance the heat energy and large woody debris of streams. The Review concludes that with the proposed forest practices in place the range of vegetative cover desired for thermal protection and LWD recruitment to streams and adequate sources of litter from trees and understory vegetation should be present to support the aquatic food chain. The Review then states that not enough is known about nutrient cycling in forest streams to determine "adequacy" of the Plans prescriptions, or any other prescriptions. No studies exist that measure the total amount and timing of litter inputs required to maintain aquatic functions. Additionally, no studies exist that indicate the desirable loadings of nutrients and organic matter downstream.

The Review concludes that applying the RMZ prescriptions in the Plan will protect the fish-habitat streams sufficiently to maintain near-maximum effectiveness of litter input sources. For non-fish-habitat waters the probable amount of litter input will be less than maximum. The Review concludes that this reduction in litter delivery may not be important for maintaining aquatic systems, or may be compensated by adjustments in in-stream photosynthesis, terrestrial vegetation, and aquatic communities that change in equilibrium with the physical stream conditions.

Summary

Chapter 2 of this document contains detailed reviews of the scientific foundations of the *Forests and Fish* plan. The chapter is organized into discussions of the functions that the *Forests and Fish* Plan are designed to enhance.

Here's what the review says about the effectiveness of the buffer zones that are recommended in the Forest and Fish Plan for each function.

Large woody debris (LWD):

The *Forests and Fish* Plan proposes to maintain and enhance large woody debris recruitment through several prescriptions related to: riparian management zones (RMZS) and sensitive site RMZS, management of potentially unstable slopes and landforms, forest road management, and wetland protection. In other words, riparian management zones are one tool that is used for management of LWD.

The Review concludes that "Riparian forests that maintain growth trajectories toward desired future conditions that are similar to mature forests are presumed to provide adequate and functional levels of LWD to streams. The *Forests and Fish* plan proposes silvicultural options for management of LWD that protects LWD sources where they are most needed and at locations where LWD can be most effective, particularly near aquatic resources and along fish-habitat streams. Proposed prescriptions would provide varying amounts of LWD to all streams and in relation to channel type and presence of fish habitat".

"The prescriptions in the *Forests and Fish* plan propose buffers and leave-tree areas for riparian management zones and potentially unstable slopes to maintain LWD supply. They would be more restrictive than the old forest practices rules. Indications are that the proposed prescriptions would contribute less than the maximum LWD recruitment potential, but an amount similar to natural circumstances, and likely to be effective for forming fish and riparian habitat. In addition, the proposed new water-typing system would extend buffer zone protection over a larger portion of the stream network than the old rules because it would protect all fish habitat, not just fish habitat that is currently occupied by fish."

Heat energy:

Riparian management zones are the primary tool that is used in the *Forests and Fish* Plan to maintain shade in streams. The Review concludes that:

"Where the riparian stands at the time of harvest meet or exceed the shade target, the Shade Rule provides assurances that, baring catastrophic loss following harvest, adequate shade would be maintained along fish-habitat streams. Where stands present at the time of harvest are not providing adequate shade, the *Forests and Fish* plan would maintain more than adequate buffer widths to allow development of the shade potential of riparian forests. The prescriptions would provide varying amounts of shade, not unlike many unmanaged forests. These may be less than the maximum potential shading, but would maintain water temperatures at or below state water quality standards in most situations."

"In cases where the existing riparian stands at the time of harvest would not meet shade targets, they also would be unlikely to meet the DFC trajectory. Therefore, harvest would not be allowed within the area that could influence shading of the stream. Water temperature in perennial non-fish-habitat stream reaches may increase over limited distances as a result of staggered shade retention zones, but these changes are not expected to affect beneficial uses of downstream fish-habitat waters because strategic watershed locations would be shaded and stream temperature relaxes toward equilibrium with the surrounding environment."

Coarse sediment:

The prescriptions in the *Forests and Fish* plan that relate to coarse sediment have to do with identifying source areas and road management, not specifically riparian buffers. The Review concludes that the *Forests and Fish* plan contains a clear and defensible list of the diagnostic landforms of Washington that are potentially unstable, and an administrative process for identifying, reviewing, and regulating forest practices on potentially unstable slopes.

Fine Sediment:

The *Forests and Fish* plan includes numerous prescriptions to address the potential for delivery of fine sediment from roads and timberlands. The plan addresses fine sediment inputs from roads through proposed programmatic and prescriptive rule changes. Surface erosion within riparian harvest units is addressed through the use of riparian management zones. That is, RMZS are one tool that is utilized to reduce forestry impacts to fine sediment in streams.

The Review concludes that "Overall, the plan appears to contain appropriate ingredients for significantly reducing the effects of forest practices that otherwise could deliver excessive fine sediment to public resources.

Hydrology:

RMZS are one tool in the *Forests and Fish* Plan to protect hydrology. Other tools are forest road management and wetland protection. The Review concludes that, "The riparian prescriptions that address hydrologic processes (and CMZs) are expected to provide a higher level of hydrologic protection [than the old forest practices rules]. Sensitive Site RMZs emphasize tree retention around seeps, springs, and forested wetlands, which may be hydrologically sensitive. Channel migration zones are recognized as part of the channel, and therefore are included within the no-harvest portion of the RMZ. These measures protect shallow subsurface flows beneath and adjacent to these streams, which are important for supporting a variety of aquatic organisms."

Pesticides:

The *Forests and Fish* Plan includes prescriptions for the application of herbicides within the RMZ. These prescriptions are expected to reduce the direct entry of herbicides into aquatic habitats. The Review concludes that, "Water quality standards have not been shown to be exceeded when herbicide is applied according to EPA labels and forest practices rules. The *Forest and Fish* plan would further reduce the potential for undesirable impacts to surface waters and streamside vegetation by restricting aerial herbicide applications in the core and inner riparian zones along fish-habitat-streams and wetlands, and applying off-sets that vary with wind conditions, application height, and nozzle type."

Litterfall:

A number of prescriptions in the *Forests and Fish* plan simultaneously address a number of riparian functions including input of organic litter to streams. All the proposed prescriptions in the *Forests and Fish* plan which address riparian vegetation management, including establishment of RMZS, have the potential to directly or indirectly influence the input of litter to streams and wetlands. The Review concludes, "The proposed prescriptions would contribute less than the maximum potential organic litter delivery, but an amount and quality likely to be functionally effective for fish and other aquatic resources."

The overall conclusion of the review is that "The *Forests and Fish* plan contains biologically sound and economically practical solutions that will improve and protect riparian habitat on non-federal forestlands in Washington."

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USGS (US Geological Survey). 1996. Occurrence of selected trace elements and organic compounds and their relation to land use in the Willamette River Basin, Oregon, 1992-1996. US Geological Survey, Washington, DC. Water Resources Investigation Report No. 4234.

Appendix A.11

REMM Model (in process, not available)

Appendix A.12

Vegetated Stream Riparian Zones: Their Effects on Stream Nutrients, Sediments, and Toxic Substances

Appendix A.12

Correll, D. 2001. Vegetated Stream Riparian Zones: Their Effects on Stream Nutrients, Sediments, and Toxic Substances An Annotated and Indexed Bibliography of the world literature including buffer strips, and interactions with hyporheic zones and floodplains. Sustainable Florida Ecosystems, Inc., 3970 N. Timucua Point, Crystal River, FL 34428 USA Tenth Edition, September 2001

The goal of this document is to comprehensively cite and subject index the world literature on vegetated stream riparian zone water quality effects. The scope of the bibliography has been expanded to include literature on hyporheic zone and floodplain/stream channel interactions. Buffer strip research is also included, since these studies seem easily transferable. This document is a bibliography. It does not contain any research information in and of itself but simply refers to other literature. It does not contain data or facilitate evaluation of the science of buffer widths on any landscapes including agricultural.

Appendix A.13

Water Quality and Agriculture: Status, Conditions, and Trends

Appendix A.13
USDA-NRCS. 1997. Water Quality and Agriculture: Status, Conditions, and Trends. Natural Resources Conservation Service Working Paper #19.

Agricultural Impacts Information:

This paper provides a substantial overview of identified and potential agricultural impacts that can affect water quality, including: sedimentation, nitrates, animal wastes, and pesticide loss in field run-off.

The paper does identify several measures that can be applied to reduce water impacts from agricultural production. These include the following:

Soil erosion and sedimentation:

- Water efficient application systems and management for irrigation.
- Crop rotations and cover crops.
- No-till or conservation tillage practices were viable.

Nitrogen use problems:

- Water efficient application systems and management for irrigation.
- Crop monitoring for nitrogen pick-up rate and optimal applications; efficient application rates.
- Crop rotations and cover crops.
- Vegetative filter strips.

Animal wastes:

- Efficient pasture management and field rotations for livestock.
- Adequate containment and control measures for waste management.
- Water efficient application systems and management for irrigation.

Pesticide loss and residues:

- Compliance with recommended application rates.
- Careful monitoring of crop conditions and optimal use of pesticides; improve pesticide application timing to reduce application rates.
- Use integrated pest management methods where possible.
- Water efficient application systems and management for irrigation.

The use of buffers, as a water quality management tool for agriculture, is not given as much attention as other management actions. The focus is on targeted management actions to reduce impacts or the potential for impacts rather than buffers to mitigate for impacts**.** In summary, the authors, using Best Available Science, provide alternatives to maximum buffer widths as a means to address proper ecological function in agricultural streams (AgFishWater Review emphasis)

Appendix A.14

Final Environmental Impact Statement for the Wild Salmonid Policy

Appendix A.14
Washington Department of Fish and Wildlife. 1997. Final Environmental Impact Statement for the Wild Salmonid Policy. Olympia, Washington.

This document is a programmatic EIS for the wild salmonid policy that Washington State has adopted. The purpose of the proposed Wild Salmonid Policy (WSP) is to, "protect, restore, and enhance the productivity, production, and diversity of wild salmonids and their ecosystems to sustain ceremonial, subsistence, commercial, and recreational fisheries; non-consumptive fish benefits; and other related cultural and ecological values". The critical issues actions described in a Wild Salmonid Policy include fishery management issues, hatchery operations, spawning numbers, and habitat matters. Riparian buffers are included in the discussion of habitat matters.

Under the agency's preferred alternative, "habitat protection and restoration would occur primarily through locally-based watershed planning that would have the flexibility to adapt performance measures and action strategies to local conditions. State and local or federal regulatory authorities would not be relinquished during locally-based watershed planning, but these authorities should be used in a manner that supports locally-based planning. Regulatory action could be taken wherever standards and requirements are not being met, and voluntary actions are either not being taken or are insufficient to achieve compliance. Statewide planning or rule-making would occur on a collaborative basis."

The report states that, "There are no single, agreed-upon, statewide numeric standards for riparian areas or wetlands. Because the Department of Natural Resources maintains and updates a fairly extensive, and fairly accurate, water typing system (defined and mapped per WAC 222-16-030), and since many local governments use this system, we would use that system as a point of reference. It should be noted that the performance measures below provide general guidance for riparian buffers that protect aquatic functions and salmonid fish habitat. These buffers should be applied regardless of land use (e.g., forest lands, agricultural, rural, or urban lands)."

"Regional or watershed specific standards may need to be applied, based upon watershed analysis, the development of specific and detailed standards in individual watershed plans, or other assessments of site conditions and intensity of land use. It is anticipated that statewide standards for state and private forest lands would be developed through the TFW process, and provided to the Forest Practices Board for formal rule making. It is also anticipated that, in many instances, existing encroachments in riparian areas or parcel size and configuration, may preclude attainment of riparian buffers".

"Nonetheless, in the absence of any other quantified alternative that provides riparian area functions described above the performance measures below are recommended to maintain functions and conditions which protect salmonid habitat:

1. Riparian Areas
    a. For Water Types 1-3, a buffer of 100 - 150 feet (measured horizontally), or the height of a site potential tree in a mature conifer stand (100 years), whichever is greater, on each side of the stream.
    b. For Type 4 streams, a buffer of at least 100 feet (each side)
    c. For Type 5 streams, a buffer of at least 50 feet (each side).
    d. For streams not administered directly or indirectly per WAC 222-26-030, apply a buffer of 100-150 feet each side on salmonid streams larger than 5 feet wide, a buffer of 100 feet (each side) on smaller perennial streams, and a buffer of 50 feet (each side) on all other streams.
    e. The buffers may need to be expanded to accommodate anticipated channel migration, as an additional buffer against windthrow, or to address upslope instability.
    f. Type 4 and 5 streams, with low stream gradient and relatively flat slope topography, may not need the full buffer width and the buffer width may be reduced to that necessary to protect the stream from upslope sedimentation and significant changes in stream temperature. The actual buffer width and composition should be based on site-specific conditions.
    g. To the extent possible, buffers should be continuous along the stream channel. Selective tree removal may occur where site review and prescription clearly demonstrates removal can occur without significantly affecting the function of the riparian area, or that removal and subsequent rehabilitation will improve the functional characteristics of the riparian area. Complete removal should be limited to road alignments, stream crossings, or other corridors where no feasible alternative exists.
    h. Riparian area restoration is strongly recommended. Plant community structural complexity (understory herbaceous and woody overstory canopy) and density should be similar to what would occur at the site under natural conditions (also known as site potential).
    i. Grazing, if allowed, should be managed to maintain or allow reestablishment of functional riparian vegetation. Other management activities occur within the riparian area, provided the functional characteristics of the riparian area necessary to protect the stream are not significantly impaired.
    j. The performance measures for Basin Hydrology and In-stream Flow, and Water and Sediment Quality and Sediment Transport and Stream Channel Complexity, should also be met to ensure riparian functions will be meaningful and attainable".

Appendix A.15

Riparian Buffer Literature Review

Appendix A.15

List of 20 Citations

Appendix B

Review of Best Available Science, WAC 365-195-900

Appendix B
Review of Best Available Science, WAC 365-195-900

Background Purpose

- Counties and cities planning under RCW development regulations must include "best available science" when developing policies and development regulations to protect the functions and values of critical areas and must give "special consideration" to conservation or protection measures necessary to preserve or enhance anadromous fisheries. (RCW 36.70A1.72(1).)
- The rules in WAC 365-195-900 are intended to assist counties and cities in identifying and including the best available science in newly adopted policies and regulations in the periodic review of plans and regulations under the Growth Management Act. (RCW 36.70A.130.)

WAC 365-195-905

Criteria for determining which information is the "best available science

- The ordinance provides assessment criteria to assist counties and cities in determining whether information obtained during development of critical areas policies and regulations constitutes the "best available science."
- Entities should consult (when feasible) with qualified scientific experts. The scientific experts may rely on professional judgment but should use criteria in the ordinance and technical guidance provided by the department.
- Entities may use information that local, state or federal natural resources agencies have determined represents the best available science if it is consistent with criteria set out in this ordinance.
- The use of criteria should guide entities but the criteria is not intended to be a substitute for assessment and recommendation by a qualified expert.
- To assess whether an expert is qualified or not is determined by the person's professional credentials and/or certification, any advanced degrees earned in the pertinent scientific discipline from a recognized university, the number of years of experience, recognized leadership in the discipline, formal training in the specific area of expertise, and field and/or laboratory experience with peer-reviewed publications or other professional literature.

To ensure that the best available science is being included, meaning scientific information produced through a valid scientific process, the entity should consider the following:

A. Characteristics of a valid scientific process.

The characteristics generally to be expected in a valid scientific process are as follows:

1. Peer reviewed
   The information has been critically reviewed by other qualified scientific experts, and the proponents of the information have addressed the criticism. Publication

in a refereed scientific journal usually indicates that the information has been appropriately peer-reviewed.

2. Methods
   The methods used were clearly stated, replicatable, and standardized in the discipline. If not standardized then the methods have been peer-reviewed.

3. Logical conclusions and reasonable inferences.
   The conclusions presented are based on reasonable assumptions supported by other studies and consistent with the general theory underlying the assumptions. The conclusions are logically and reasonably derived from the assumptions and supported by the data presented. Gaps in information and inconsistencies with other pertinent scientific information are adequately explained.

4. Quantitative analysis
   The data have been analyzed using appropriate statistical or quantitative methods.

5. Context
   The information is placed in the proper context meaning that the assumptions, analytical techniques, data, and conclusions are appropriately framed with respect to the prevailing body of pertinent scientific knowledge.

6. References
   The assumptions, analytical techniques, and conclusions are well referenced with citations to relevant, credible literature and other pertinent existing information.

Common Sources of Scientific Information

- Some sources of information routinely exhibit all or some of the characteristics listed above, and a city or county may consider information to be scientifically valid if the source possesses the characteristics listed above.
- Information derived from the following sources may be considered scientific if the source possesses certain combinations of the above characteristics.

Sources of scientific information

Research

- Meaning: Data collected and analyzed as part of a controlled experiment to test a scientific hypothesis.
- To be considered scientific information the research must posses the following characteristics:
  - Peer review, methods, logical conclusions and reasonable references, quantitative analysis, context, references.

Monitoring

- Meaning: Data collected periodically over time to determine a resource trend or evaluate a management program.
- To be considered scientific information the monitoring must possess the following characteristics:
    - Methods, logical conclusions and reasonable references, context, references. Additionally, the presence of quantitative analysis strengthens the scientific validity and reliability of information, but is not necessary.

Inventory

- Meaning: Data collected from an entire population or population segment.
- To be considered scientific information the inventory must possess the following characteristics:
    - Methods, logical conclusions and reasonable references, context, references. Additionally, the presence of quantitative analysis strengthens the scientific validity and reliability of information, but is not necessary.

Survey

- Meaning: Data collected from a statistical sample from a population or ecosystem.
- To be considered scientific information the survey must possess the following characteristics:
    - Methods, logical conclusions and reasonable references, context, references. Additionally, the presence of quantitative analysis strengthens the scientific validity and reliability of information, but is not necessary.

Modeling

- Meaning: Mathematical or symbolic simulation or representation of a natural system. Models generally are used to understand and explain occurrences that cannot be directly observed.
- To be considered scientific information the modeling must posses the following characteristics:
    - Peer review, methods, logical conclusions and reasonable references, quantitative analysis, context, references.

Assessment

- Meaning: Inspection and evaluation of site-specific information by a qualified scientific expert. An assessment may or may not involve collection of new data.
- To be considered scientific information the assessment must possess the following characteristics.
    - Methods, logical conclusions and reasonable inferences, context, and references

Synthesis

- Meaning: A comprehensive review and explanation of pertinent literature and other relevant existing knowledge by a qualified scientific expert.

- To be considered scientific information the synthesis must posses the following characteristics:
  - Peer review, methods, logical conclusions and reasonable references, context, references.

Expert Opinion

- Meaning: Statement of a qualified scientific expert based on his/her best professional judgment and experience in the pertinent scientific discipline. The opinion may or may not be based on site-specific information.
- To be considered scientific information the synthesis must posses the following characteristics:
  - Logical conclusions and reasonable references, context, and references.

Nonscientific Information

- Information from nonscientific sources (i.e., information the does not exhibit the necessary characteristics for scientific validity and reliability) is not an adequate substitute for scientific information although it may be used to supplement scientific information.

Common sources of nonscientific information include:

i. Anecdotal information.
   Observations that are not part of an organized scientific effort.
ii. Nonexpert opinion
iii. Hearsay
   Information repeated from communication with others.

WAC 365-195-910
Criteria for Obtaining the Best Available Science

- Suggests consulting with state and federal natural resources agencies and tribes to develop scientific information and recommendations.
- If an entity compiles scientific information it should assess whether the scientific information constitutes the best available science using the criteria in this ordinance and any technical guidance provided by the department.

WAC 365-195-915
Criteria for Including the Best Available Science in Developing Policies and Development Regulations

- To demonstrate that the best available science has been included in the development of critical areas policies and regulations, entities should address each of the following on the record:
  (a) The specific policies and development regulations adopted to protect the functions and values of critical areas at issue.
  (b) The relevant sources of best available scientific information included in the decision-making.

(c) Any nonscientific information used as a basis for critical areas policies and regulations that depart from the recommendations derived from best available science.
   - If an entity departs from science-based recommendations it should
   (i) Identify the information in the record that supports its decision to depart from science-based recommendations.
   (ii) Explain its rationale.
   (iii)Identify potential risks to the functions and values and any additional measures chosen to limits the risks.

- Entities should include best available science in determining whether to grant variances and exemptions from provisions in policies and development regulations protecting critical areas.

WAC 365-195-920
Criteria for Addressing Inadequate Scientific Information

- Entities should take the following approach when uncertainty exists regarding which development and land uses could harm critical areas due to a lack of valid or incomplete scientific information.
  1. Precautionary approach
     - Activities are strictly limited until uncertainty is resolved
  2. Use an effective adaptive management program that relies on scientific methods to evaluate how well regulatory and nonregulatory actions achieve their purposes. Management, policy and regulatory actions are monitored and evaluated to determine if they are effective and if not determine how to increase effectiveness.

WAC 365-195-925
Criteria for demonstrating "special consideration" has been given to conservation or protection measures necessary to preserve or enhance anadromous fisheries

- In addition to the requirement that cities and counties include the best available science when developing policies and management decisions, entities must give "special consideration" to conservation or protection measures necessary to preserve or enhance anadromous fisheries.
- The entity must include in the record evidence that it has given "special consideration" to conservation or protection measures using the criteria in the ordinance to ensure these measures are grounded in the best available science.
- These measures include measures that protect habitat important for all life stages of anadromous fish.
- Special consideration should be given to habitat protection measures based on best available science relevant to stream flows, water quality and temperature, spawning substrates, instream, structural diversity, migratory access, estuary and nearshore marine habitat quality, and the maintenance of salmon prey species.

Appendix C

Notes and Additional References on Agricultural Production Values

Appendix C
Notes and Additional References on Agricultural Production Values

Livestock and Direct Products

The following outlines how the calculations in the above summery tables (and other more detailed spreadsheets) were made. The discussion is by each livestock animal or commodity (milk production). The methodology is much the same between each. As a result, once the process is explained, only differences between the basic approaches will be noted.

Sheep

Value of sheep and lambs sold and slaughtered is determined by taking the state level year end inventory (obtained from Washington State Department of Agriculture statistical publication, see references below) and dividing that into the number of sheep and lambs sold or slaughtered (including farm slaughter) times the estimated inventory of animals at the county level. County level inventory is based on U.S. Department of Agriculture's 97 Census of Agriculture estimated inventory of sheep and lambs at the individual county and state level. The percentage change in inventory at the state level from year to year is then taken times the base 1997 county inventory to arrive at the estimated number of sheep and lambs sold or slaughtered at the county level for a particular year.

Example – Benton – 1998

> Lambs/sheep sold or slaughtered at the state level: 61,300
> Final inventory of sheep and lambs at the state level: 50,000
> 61,300/50,000 = 1.23 number of animals sold or slaughtered to base year inventory
> 50,000 year end 1998 inventory/53,000 1997 year end inventory = 0.9437 decrease in inventory 1997 to 1998
> 1208 97 year end inventory for Yakima County X 0.9437 = 9857 X 1.23 = 1,397 sold/slaughtered in 1998

The next step is to determine average price per animal. This was accomplished by taking the gross income for the year in question and dividing it by the total number of sheep and lambs sold or slaughtered. All dollar values are adjusted to 2000$ using the Gross Domestic Product implicit price deflator.

For Yakima and Kittas counties updated inventory data were used (Livestock Rankings, Washington 1999). In this case, the 1999 inventory data was as of January 1, 1999, or in effect December 31, 1998. So these numbers were used as the basis of inventory for 1998. And then the same process employed, as previously described, to modify the year-end inventory figures and to estimate the number of animals sold or slaughtered.

Sources:

Washington State Department of Agriculture. Sheep and Lambs. http://www.nass.usda.gov/wa/annual01/sheep01.pdf. (Accessed June 30, 2002).

United State Department of Agriculture. Livestock Rankings, Washington. 1999. National Agriculture Statistical Service (NASS). http://www.nass.usda.gov/wa/counties/lvstrank.htm (Accessed June 30, 2002).

United State Department of Agriculture. 1997 Census of Agriculture. Highlights of Agriculture: 1997 and 1992. Skagit County, Washington. National Agriculture Statistical Service (NASS). http://www.nass.usda.gov/census/census97/highlights/wa/wac029.txt (Accessed June 30, 2002).

United State Department of Agriculture. 1997 Census of Agriculture. Highlights of Agriculture: 1997 and 1992. Benton County, Washington. National Agriculture Statistical Service (NASS). http://www.nass.usda.gov/census/census97/highlights/wa/wac003.txt (Accessed June 30, 2002).

United States Department of Commerce. Bureau of Economic Analysis. Gross Domestic Product (GDP) and Implicit Price Deflator of GDP. http://www.info.gov.hk/censtatd/eng/hkstat/fas/nat_account/gdp/gdp1.htm (Accessed June 27, 2002).

Cattle and Calves

A similar process was employed for cattle and calves as for sheep and lambs. In this case, we had aninventory of all cattle for each of the four counties effective January 1, 1999. These numbers in effect became our year-end numbers for 1998 and then adjusted by the process previously described. Total income was derived in the same manner and expressed in 2000$.

Sources:

Washington State Department of Agriculture. Cattle and Calves. http://www.nass.usda.gov/wa/annual01/cattle01.pdf. (Accessed June 27 2002).

United States Department of Commerce. Bureau of Economic Analysis. Gross Domestic Product (GDP) and Implicit Price Deflator of GDP. http://www.info.gov.hk/censtatd/eng/hkstat/fas/nat_account/gdp/gdp1.htm (Accessed June 27 2002).

Hogs and Pigs

Again, a similar process was employed for hogs and pigs as for sheep and lambs. The 1997 Census of Agriculture was used for Benton and Skagit counties and adjusted across 1998 to 2000 based on changes in state level data for those years. For Yakima and Kittas counties we had farm inventory data for December 31, 1998 and used this data to scale for these two counties. In this case, we had inventory of all cattle for each of the four counties effective January 1, 1999. Total income was derived in the same manner and expressed in 2000$.

Sources:

Washington State Department of Agriculture. Hogs and Pigs. http://www.nass.usda.gov/wa/annual01/hogs01.pdf. (Accessed June 27 2002).

United States Department of Commerce. Bureau of Economic Analysis. Gross Domestic Product (GDP) and Implicit Price Deflator of GDP. http://www.info.gov.hk/censtatd/eng/hkstat/fas/nat_account/gdp/gdp1.htm (Accessed June 27 2002).

United State Department of Agriculture. 1997 Census of Agriculture. Highlights of Agriculture: 1997 and 1992. Skagit County, Washington. http://www.nass.usda.gov/census/census97/highlights/wa/wac029.txt (Accessed June 30, 2002).

United State Department of Agriculture. 1997 Census of Agriculture. Highlights of Agriculture: 1997 and 1992. Benton County, Washington. http://www.nass.usda.gov/census/census97/highlights/wa/wac003.txt (Accessed June 30, 2002).

Milk Production

For milk production (total market value all products), the 1997 Census of Agriculture was used to determine the total number of milking cows for Benton and Kittas counties. These values were then scaled, as previously described, employing state data. For Skagit and Yakima counties data that are more recent existed for the inventory of milk cows in these counties. The inventory date was as of January 1, 1999, or effectively December 31, 1998. These values were employed for 1998 and then scaled as previously described using state data.

The value of milk production per cow is determined by dividing the value of milk produced (inclusive of all mile products) by the average annual number of milk cows in Washington State. These values (per cow) were then multiplied by the estimated inventory of milk cows in each county.

Sources:

Washington State Department of Agriculture. Manufactured Dairy Products. http://www.nass.usda.gov/wa/annual01/milkpr01.pdf. (Accessed June 27, 2002).

United States Department of Commerce. Bureau of Economic Analysis. Gross Domestic Product (GDP) and Implicit Price Deflator of GDP. http://www.info.gov.hk/censtatd/eng/hkstat/fas/nat_account/gdp/gdp1.htm (Accessed June 27 2002)

United State Department of Agriculture. 1997 Census of Agriculture. Highlights of Agriculture: 1997 and 1992. Benton County, Washington.

http://www.nass.usda.gov/census/census97/highlights/wa/wac003.txt (Accessed June 30, 2002).

United State Department of Agriculture. 1997 Census of Agriculture. Highlights of Agriculture: 1997 and 1992. Kittas County, Washington. http://www.nass.usda.gov/census/census97/highlights/wa/wac019.txt (Accessed June 30, 2002).

Methodology Employed in Deriving
Farm Gate Value for Orchard and Crops for
Benton, Kittas, Skagit and Yakima Counties
1998 – 2000

Field Crops and Orchards

Field crops information for the four counties was obtained from the U.S. Department of Agriculture (USDA), National Agricultural Statistical Service's (NASS) on-line database. Values for the following crops were available for 1998 to 2000: barley, all; beans, all dry edible; beans, pink; beans, pinto; beans, small red; bean, small white; beans-dry edible, white, small flat; corn for grain and silage; green peas for processing; hay – alfalfa (dry), all (dry) and other (dry); oats; potatoes, all; sugar beets; wheat, all, other spring, and winter all. These data were used directly in the table.

Data for orchard crops for acres planted was available only for 1997. The assumption was made that these acreages would not materially change as far as productive acreage between 1998 and 2000. Thus, 1997 acreage values were used for orchard crops (1998 to 2000) unadjusted. However, it is acknowledged that there have been major changes in the apple industry over these years. Unfortunately, updated information by county reflecting these changes was not available.

Prices and values per acre (when yields per acre were not available for some crops) were determined using Washington State Department of Agriculture statistics for each year in the analysis. All dollar values are adjusted to 2000$ using the Gross Domestic Product implicit price deflator.

Sources:

U.S. Department of Agriculture. National Agriculture Statistical Service (NASS). Published Estimates Data Base – County Washington Crops Grouping – Benton, Kittas, Skagit and Yakima Counties. http://www.nass.usda.gov:81/ipedb/. (Accessed June 30, 2002).

U.S. Department of Agriculture. National Agriculture Statistical Service (NASS). 1997. Orchard Rankings, Washington. http://www.nass.usda.gov/wa/counties/orchrank.htm#appl. (Accessed June 30, 2002).

Washington State Department of Agriculture. 2001. "Top Forty Agricultural Commodities, Washington." Washington 2001 Annual Bulletin. http://www.nass.usda.gov/wa/annual01/top40_01.pdf. (Accessed June 30, 2002).

Washington State Department of Agriculture. 2002. Fast Facts. Latest Crop, Livestock and Economic Estimates for Washington. http://www.nass.usda.gov/wa/. (Accessed June 30, 2002).

Washington State Department of Agriculture. 2002. Washington Agri-Facts. http://www.nass.usda.gov/wa/agri2feb.pdf. (Accessed June 30, 2002).

United States Department of Commerce. Bureau of Economic Analysis. Gross Domestic Product (GDP) and Implicit Price Deflator of GDP. http://www.info.gov.hk/censtatd/eng/hkstat/fas/nat_account/gdp/gdp1.htm (Accessed June 27, 2002).